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NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC
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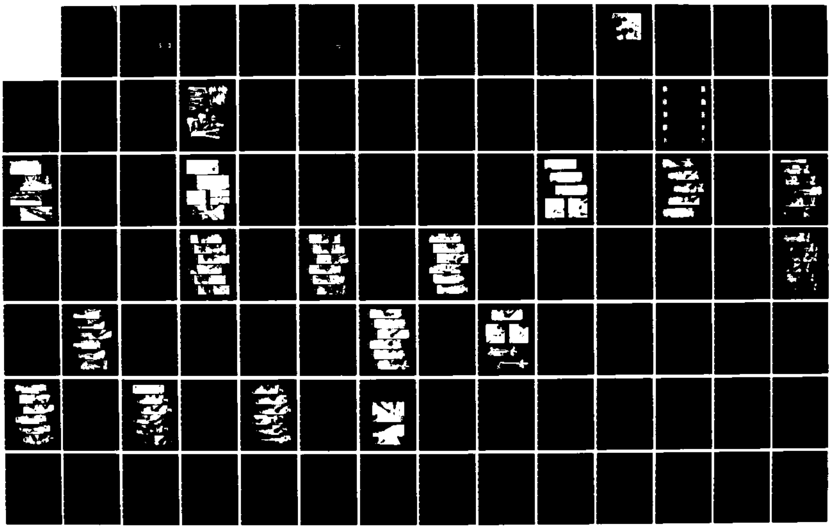

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MANUAL FOR FIELD SPLICING OF HARBOR DEFENSE CABLES

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FPO-1-82(4)
JANUARY 1982

PREPARED BY

ROBERT TAGGART INCORPORATED
FAIRFAX, VIRGINIA

FOR

OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D. C. 20374

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The Chesapeake Division, Naval Facilities Engineering Command ~~(CHESNAVFAC-ENGCOM)~~ Ocean Engineering and Construction Project Office has in storage some 325 miles of harbor defense submarine cable. This cable ranges from single conductor coaxial cable to sixteen conductor cable and widespread use (Con't)

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is anticipated by this organization and other government activities engaged in ocean construction projects.

The available cable is stored on reels ~~of a few thousand feet each. Thus~~ for most project use, field splicing of the cable will be required, to make up the lengths required for each total run of cable. Although many organizations have developed splicing techniques and equipment that are entirely satisfactory for their own specific purposes, it is also true that in many cases, outside experts must be called in to perform field spices during the course of construction activities.

The Ocean Engineering and Construction Project Office has frequently found itself in the latter situation and has therefore undertaken the preparation of this field splicing manual for its own use and for the use of other government activities and contractors that may be involved in ocean construction projects where cable splicing in the field is required. The splicing techniques, developed and used equipment, tools, and materials illustrated and described herein have been developed and ~~used~~ by Arthur L. Nelson & Company. While other methods and combinations of methods my be employed as conditions dictate, It has been found that these splicing techniques resulted in splices having the electrical, mechanical, and structural integrity essential to withstanding the rugged conditions encountered in the ocean construction environment.

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CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
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FOREWORD

The Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) Ocean Engineering and Construction Project Office has in storage some 325 miles of harbor defense submarine cable. This cable ranges from single conductor coaxial cable to sixteen conductor cable and widespread use is anticipated by this organization and other governmental activities engaged in ocean construction projects.

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It is anticipated that this document will be useful as an instruction book for those who are to perform cable splices in the field. It will also serve as a planning document for ensuring that the required facilities, equipment, tools, and materials are procured and delivered to the construction site and that adequate time is allowed both for splicing and for conducting the necessary electrical tests during cable-laying operations.

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NAVY STANDARD HARBOR DEFENSE SUBMARINE CABLES

The cables covered by this splicing manual are standard submarine cables for use in harbor defense systems. They are used for loop, signal, control, and hydrophone components in an inshore environment. Essentially their use is restricted to functioning as the shore end of deep sea cables or they are used to form interconnections between system components and for making shore connections from underwater devices implanted offshore.

The Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) has acquired approximately 400 miles of harbor defense cable of which some 325 miles is stored for future use. This cable was originally manufactured under specification MIL-C-15479B (SHIPS) dated 1 September 1954. This has now been replaced by "Military Specification, Cables, Power, Electrical, Submarine, Navy Standard Harbor Defense" MIL-C-15479C (SHIPS) dated 17 March 1958. A copy of this latter specification is included as Appendix A to this manual.

CABLE FUNCTIONS AND CHARACTERISTICS

These submarine cables are of the following five types:

Type 201 - Single conductor armored coaxial signal cable
Type 203 - Three conductor armored magnetic loop tail cable
Type 204 - Four conductor armored lateral or main hydrophone cable
Type 210 - Ten conductor armored herald control and magnetic loop control cable
Type 216 - Sixteen conductor armored main hydrophone cable

CHESNAVFACENGCOM has in storage approximately 250 miles of Type 203 cable and the remaining 75 miles is divided between Types 201, 204, 210, and 216. The cable cross sections are illustrated in Figure 1 and their characteristics are summarized in the table below the photograph.

It will be noted that the 1958 Military Specification for these cables replaces a 1954 version. Some of the cable in the CHESNAVFACENGCOM stock antidates even that earlier specification. For example, the Type 216 cable furnished from stock for developing the splicing procedures depicted herein was manufactured in 1951, the Type 204 cable was dated 1959 but there are some differences between the cable furnished and the 1958 specification.

CROSS SECTIONS OF STANDARD HARBOR DEFENSE CABLES

FIGURE 1

CABLE TYPE		201	203	204	210	216
NUMBER OF CONDUCTORS		1	3	4	10	16
CONDUCTOR WIRE SIZE AWG		8	10	14	14	14
CONDUCTOR WIRE O.D.		0.178	0.138	0.090	0.090	0.085
CONDUCTOR STRANDS		7	7	7	7	7
CONDUCTOR STRAND O.D.		.0490	.0400	.0253	.0253	.0253
CONDUCTOR INSULATION O.D.	>	0.460	0.304	0.176	0.176	0.183
CONDUCTOR INSULATION WALL THICKNESS	>	0.141	0.083	0.043	0.043	0.049
SHIELDING BRAID WIRE SIZE		28	–	–	–	28
SHIELDING BRAID WIRE DIA.		.0126	–	–	–	.0126
INNER JACKET, O.D.	± .015	0.749	0.885	0.655	0.935	1.120
JACKET MINIMUM WALL THICKNESS		0.093	0.093	0.093	0.093	0.093
ARMOR WIRE DIAMETER	± .004	0.134	0.134	0.109	0.134	0.134
NUMBER OF ARMOR WIRES		18	21	17	22	24
OUTER JACKET THICKNESS	≧	.1875	.1875	.1875	.1875	.1875
OUTER JACKET (CABLE) O.D.	≦	1.465	1.602	1.321	1.651	1.836

DIMENSIONS ARE IN INCHES

One difference may be found in the number of armor wires for each cable. Below are listed the minimum number of armor wires that would meet the 1958 specification and the actual number of wires counted on the available samples.

Cable Type	201	203	204	210	216
Specified number of wires	19	21	20	22	26
Number of wires in sample	18	21	17	22	24

In the drawings of the cables given later in the manual, the number of wires counted in the samples are given. Similarly, the outside diameters of the armor wire bundle (which are not specified) are those measured on the available samples. When this dimension is required for ordering armor restoration materials, it should be measured on the actual cables to be used.

It was also noted that the Type 216 cable 1951 sample used did not have mylar tape wrapped around the outer core inside the inner jacket as called for in the 1958 specifications. When cutting through the inner jacket, the lack of this tape could allow the cutting thread to slice into the outer core conductor insulation which could destroy the integrity of the splice. It would therefore be prudent to check each cable to determine what elements are missing before proceeding with splicing operations.

Another discrepancy found between the 1958 specifications and the available sample cables was the color coding of the conductor insulation. This is of primary concern in splicing the multiple conductor cables and in conducting the required electrical tests on them. It is also of concern when new cable is spliced to older cable. In this respect, Types 201 and 203 were satisfactory. The Type 204 specification calls for the four conductors to be color coded black, white, red, and green whereas in the sample used, the white was replaced by a dirty white or brownish color.

The color coding discrepancy of greatest concern was in the Type 210 and Type 216 cables. The differences found are tabulated below:

	Type 210 Color Code		Type 216 Color Code	
	1958 Spec	Sample Cable	1958 Spec	Sample Cable
Inner Core	white	white	black	black
Conductors	black	black	white	brown
	-	-	red	red
	-	-	green	green

	Type 210 Color Code		Type 216 Color Code	
	1958 Spec	Sample Cable	1958 Spec	Sample Cable
Outer core	red	red	black	black
Conductors	green	black	white	brown
	yellow	green	red	black
	brown	black	green	red
	blue	orange	yellow	black
	orange	black	brown	green
	gray	blue	blue	black
	purple	black	orange	orange
			gray	black
			purple	blue
			tan	black
			pink	pink

In later instructions on electrical testing, where color codes are referred to for the first time, the color codes specified in Appendix A are used to denote what connections are to be made for test purposes. It will be up to the cable splicing activity to translate these instructions as necessary to apply the intended tests to the available cables.

CONDITIONS REQUIRING FIELD SPLICING

The cables covered by this manual are normally furnished on nonreturnable steel reels with a flange diameter no greater than 7 feet and an inside traverse no greater than 4 feet. Minimum lengths of cable that may be stowed on a single reel are 5000 feet for Types 201, 203, and 210 and 3000 feet for Types 204 and 216. The majority of inshore cable-laying projects involve greater lengths than these, thus requiring the splicing together of multiple reels of cable.

Either of two connection techniques may be employed when laying cable. In the first case, the cable reels may be stored aboard the cable-laying vessel; as the laying of one reel of cable is completed, the cable on the next reel can be spliced to it and the cable-laying continued. In the second case, the cable-laying vessel may be fitted with a cable tank or bin into which the cable can be fed from reel stands ashore and coiled down into the tank; here, the splicing can be done as each successive reel is positioned on the pier to feed the cable tank.

The first technique requires a shipboard installation where the cable reels can be conveniently moved into alignment with the cable-laying machinery or system. It also requires that the facilities, tools, and personnel for performing cable splices be aboard the cable-laying vessel. The second technique can utilize a shoreside splicing facility but the cable-laying vessel must be fitted with a tank or bin and an adequate system for laying the cable from that onboard structure. In some situations, an alternative solution is to tow the cable end out to sea from reels and winches mounted ashore where the splicing can be handled at the shore station. In one instance (AFAR-AUTEC Project) a special barge was fitted out for the sole purpose of making a splice between an inshore cable and the sea cable leading out to an implanted sonar array.

SPLICING FACILITIES, EQUIPMENT, TOOLS, AND MATERIALS

Regardless of whether the splicing is done ashore or aboard a cable-laying vessel or splice barge, the tools and materials employed will be identical. However, some variation in facilities and equipment will be required if splices are to be performed on a moving vessel at sea.

SHORE FACILITIES FOR CABLE SPLICING

Unless the environmental conditions are exceptionally good in the location where the splicing is to be done, a shelter should be provided over the splicing area, the tools, and the materials. This may range from a lean-to or tent structure to a completely enclosed splice house. However, since any dust or dirt in the air may adversely affect the quality of a splice, the enclosed splice house is preferred. Internal dimensions of the shelter should not be less than 8' x 8' x 16' if practicable.

The splicing facility should be well ventilated to prevent overexposure to inhalation of the trichloroethylene solvent used frequently during electrical splicing operations. In cold weather environments, heating facilities should be available to maintain reasonably comfortable working conditions. In addition to any heating or ventilating requirements, there should be available a 5 kw source of 125 v AC power for operation of tools and equipment.

If it is assumed that an onshore splice house will either be feeding to a tank aboard a vessel or directly out to a cable-layer at sea, there should

be facilities for leading the cable off a reel into the splice house and for feeding it out through the opposite end of the splice house via some form of winch, tensioning device, or brake. The system should permit the cable between splices to move freely from the supply reel, on through the splice area and through the cable winch, brake, or tensioner when not splicing the cable.

AFLOAT FACILITIES FOR CABLE SPLICING

A splice house aboard a cable-laying ship or barge can be quite similar to the shoreside splice house. There must be, however, adequate provision for ship motions including the movement of the cable leading from the vessel into the water relative to the vessel itself. Furthermore, provision must be made for rapidly dumping the cable overboard in the event of an emergency. This requires that an overside outlet be provided along the side of the splice house so that the cable can be ejected from the winch, tensioner, or brake and will be free to discharge directly overboard from a free running cable reel.

If a portable splice house is built for use in a number of projects it would appear logical to design it both for shoreside use and for use aboard a vessel. The overboarding feature could be closed up when the house is used ashore. The ejection slot would necessarily be on the side opposite that where personnel are performing the splicing operations. For flexibility in use aboard ship it would be logical to design the splice house in a double ended fashion so that it could be used either port or starboard on the cable-laying vessel.

EQUIPMENT

As mentioned above, two important adjuncts to the cable splice house are a cable reel stand and a linear cable winch, tensioner, or brake. The best combination of these devices for general cable-laying work should be the subject of a separate study and is not covered in detail herein. It should be noted, however, that the equipment on the output end of the splice house should be capable of passing the enlarged and stiffened section of the cable where the splice has been formed. The brake or tensioner arrangement should also have sufficient capacity to hold securely the cable which is in the water or over the pierside while the splice is being performed; this requires a fail-safe braking mechanism.

As will be seen in later illustrations in this manual, the splicing

operations can be performed quite satisfactorily with a pair of heavy, table-type work benches to each of which a pair of clamp-on machinists' vises are attached. Either the work benches or the vises can be moved to reposition the cable during the splicing operation. For field use, however, a different arrangement would be more satisfactory, particularly if a facility such as a portable splice house is to be fabricated for a number of different types of splicing operations, both ashore and at sea.

First, it should be assumed that the output end of the cable will be in a fixed longitudinal position, held by a tensioner or by a brake; the mating cable, being drawn from the cable reel, will be movable fore and aft. Yet, if the double-ended configuration is to be used, the work areas and clamping device locations should be symmetrical.

Second, on a vessel installation, arrangements must be made for overboarding the cable in an emergency. This means that the work area and work benches must be arranged so that personnel and equipment will not be located outboard of the line of the cable within the splice house nor should any tools or materials be permanently stored there. The work benches should be in a fixed location with adequate spacing between them to perform the splice.

Finally, the means of clamping the cable to the work benches should be of a quick release type, configured so that the cable will not be damaged when firmly secured and sufficiently adjustable to accommodate a range of jacket and armor diameters. This suggests that there be one clamp down device permanently affixed in the longitudinal direction near the fore and aft ends of the work benches and that the other pair of clamp down devices be movable longitudinally. All four devices would open so as not to interfere with sliding the cable overboard.

Slotted stowages for individual tools can be provided along the fronts of the work benches where the tools are readily available and yet will not be displaced by vessel motions. Bins can be provided for smaller items such as crimp connecting sleeves, hose clamps, and pencilling tools. Materials such as tapes, solder, cutting thread, Band-It straps, and small shrink sleeve tubing can be strung on a round bar above the work area where they can be easily pulled out for use. A fixed or gimballed container can be provided for the trichloroethylene solvent arranged for use with minimum spillage. Horizontal cabinet stowage can be arranged on the inboard bulkhead for such

materials as the larger shrink sleeves and preformed armor rods.

Additional equipment to be installed in the splice house will be the measurement apparatus required for the electrical testing of the cable after each splice is made. This equipment will include a DC power supply, a Wheatstone Bridge arrangement of resistors and galvanometers, and a standard capacitor. These can be rack mounted in the splice house. Additionally, there will be required one set of cable test leads in the work bench area where the splice is made and another set of test leads running out to the cable reel stand where they can be made up to the core end of the cable for testing each new reel before it is spliced into the cable. Where tank or bin storage of the cable is being used, there should be another set of cable test leads rigged to the end of the cable in the tank.

SPLICING TOOLS AND MATERIALS

Many of the tools used in various parts of the splicing operation are illustrated in the photograph, Figure 2. These are the tools used during the splicing examples given in later sections and are available from several different manufacturers. Where trade names are used it does not necessarily mean that other brands might not be equally satisfactory. These tools are designated by circled numbers on the photograph corresponding to the identifying numbers below:

1. Hack saw
2. Screwdriver
3. Knife
4. File
5. Channellock pliers
6. Diagonal wire cutters
7. Jacket cutting tool
8. Wire strippers
9. Scissors
10. Wire strippers
11. Tape measure
12. Crimping tool
13. Fixed Vise
14. Rotatable Vise
15. Soldering gun
16. Hot air gun, 14A, 600°C
17. Vise-grip pliers
18. Coreless solder wire
19. Solder paste
20. Stiff (1/2") brush
21. Tin snips
22. Band-It tool
23. Nicopress crimping tool
24. Hose clamps

TOOLS USED IN CABLE SPLICING OPERATIONS

FIGURE 2

The majority of these tools are available from several manufacturers or supply houses. However, the Band-It tool and straps may require a special order from Band-It Company, 4757 Dahlia Street, Denver, Colorado, or from one of their distributors.

A few additional special tools, not shown in Figure 2, deserve brief mention. Shoemakers' No. 6 thread-unwaxed, comes in a roll similar in appearance to the waxed string used for wire harness lacing; this thread is used as a saw to make a circular cut around and through synthetic resin jacket material and also through conductor insulation.

Pencilling tools, for all conductors except that in the Type 201 cable, can be made from pencil sharpeners of the portable, school book bag variety. Some of these sharpeners are made of die-cast aluminum with a conical internal taper and small steel blade held on the taper by a single screw. To convert this to a pencilling tool, the blade is removed and the end where the pencil point fits is machined or filed away until the hole diameter opens up to the diameter of the appropriate wire gage. The blade is then screwed back in place and the end is ground down flush with the machined-off casting. By sliding this tool on the end of a stripped wire and rotating it slowly a smooth taper can be cut on the conductor insulation.

A propane torch is useful for applying heat to shrink sleeving when the hot air gun does not put out enough heat. Using a special soldering iron tip on the torch, it can also be used for heavier soldering jobs beyond the capacity of the soldering gun.

Materials used for cable splicing include several different special types of tape. Where a manufacturer's name is given in the listing below, it is recommended that this source be used since the product is known to be reliable. This also applies to other materials that are listed by name.

- o Masking tape - used for marking sleeve endings and for securing wires in temporary positions.
- o Plastic electrical tape - used for temporarily securing wire braid or for marking purposes.
- o Mastic tape - a tar-like material in tape form used for wrapping around clusters of insulated conductors to fill in interstices when heated under a shrink sleeve.

- Rubber tape, 3M Scotch 130C - used to build up diameter of conductor cores before application of shrink sleeves.
- Polyethylene irradiated tape, General Electric No. 210 - used to replace insulation over conductors and crimp connectors; shrinks when heated and forms watertight bond with both conductor and insulation materials.
- Tinned copper wire braid electrical shielding tape, 3M Scotch 24 - used to replace shielding braid in spliced joints where it is soldered to the cable braid on either end.

The solvent used throughout the electrical process is trichloroethylene which dissolves the various mastics used in underwater cables but does not attack the synthetic resin jackets, conductor insulation, or any of the tapes or shrink sleeves used in splicing. This solvent may be obtained in quantity from any chemical supply house.

In the conductor splices described in later sections, the insulation over the spliced area is replaced first by wrapping with polyethylene irradiated tape. After heating the tape, the splice is covered with a short length of shrink sleeve tubing cut from a roll. This tubing is manufactured by the Gilbreth International Corporation, 3300 State Road, Bensalem, PA 19020. Two sizes are used for the harbor defense cable splicing. These are designated as 2021 Black Style 12-6-1 and 2021 Black Style 8-4-1. The style numbers indicate the inside diameter of the tubing as supplied, the inside diameter after heat shrinking, and the wall thickness - all in millimeters.

Larger diameter shrink sleeves made of polyolefin are used to provide insulation and a watertight bond between the inner jackets of spliced cables. These may consist of the polyolefin material alone or with that material lined with a mastic tar-like substance that performs the same function as the mastic tape. For all five harbor defense cables, the shrink sleeve size used was 2"-5/8". Here the inside diameter as supplied is 2 inches and the reduced diameter after heating can be as small as 5/8 inch. These sleeves come in standard lengths of 12 inches but other lengths can be furnished on order. They may be obtained from: Insulectro (a Quintec Industry), 7697A Formula Place, San Diego, CA 92126.

One method of armor restoration requires the use of preformed single splice rods and preformed sector-type splice rods. These come in standard

lengths of 80 inches and are specified by the wire size and outside diameter of the armor which they replace. They may be obtained from the Preformed Line Products Co., 660 Beyda Drive, Cleveland, Ohio 44143.

Crimp connecting sleeves for the conductors referred to in the text were 2C10 and 2B14 STA-KON lugs manufactured by Thomas and Betz. These lugs have a slot at the center which is particularly useful for seeing that the butting wires are completely inserted in the sleeve and for use in soldering the connector to the wires. The crimping tool shown in the illustration was of the same manufacture.

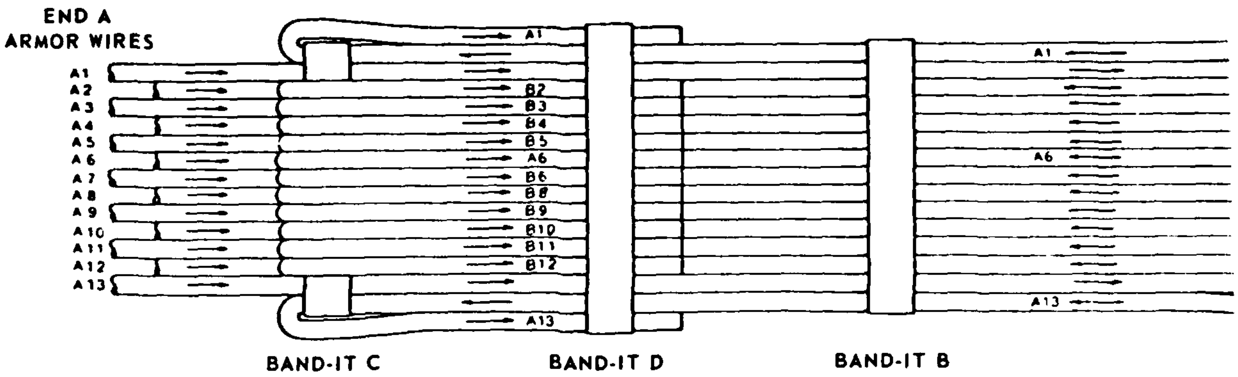
MAINTAINING CABLE STRENGTH THROUGH A SPLICE

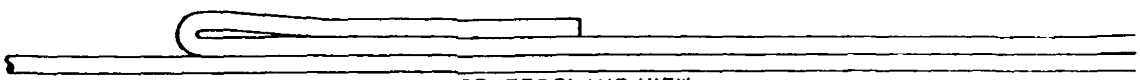
The strength members of the five harbor defense submarine cables are the armor wires that are wrapped around each cable between the inner and outer synthetic resin jackets. These armor wires are of galvanized steel with a tensile strength between 50,000 and 70,000 pounds per square inch and an elongation of not less than 10 percent after application to the cable. The armor wire is applied to the inner jacket helically with an even tension and a left hand lay at an angle of approximately 20 degrees. The number of wires on each cable is that required to insure approximately 95 percent coverage at the pitch circumference of the armor. The wire is pre-formed so that it will remain in proper position and permit maximum flexibility of the finished cable.

Surrounding the armor wire is a jacket of synthetic resin which conforms to the contours of the armor wires on the inside but has a smooth cylindrical surface on the outside. This jacket helps to hold the armor in place during bending and flexing. It also isolates the armor from seawater. Although it does not contribute to the tensile strenght of the cable, tape should be substituted for the jacket to prevent corrosion.

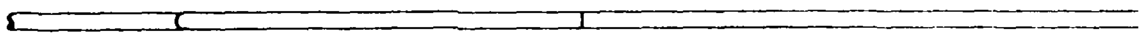
When two lengths of harbor defense submarine cable are spliced together, it is essential that the electrical connections preserve the current carrying capability of the conductors, the resistance of the insulation, and the watertight integrity of all cable components within the outer boundary of the inner jacket. The function of the armor restoration is to preserve the structural integrity of the cable and to maintain its strength across the joint between the spliced cables.

SIDE VIEW OF COMPLETED ARMOR RESTORATION F



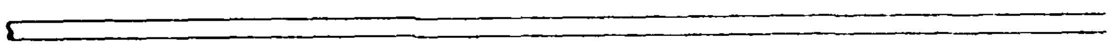


CENTERPLANE VIEW



RADIAL VIEW

CONFIGURATION FOR ARMOR WIRES A1, A6, A13, & A18



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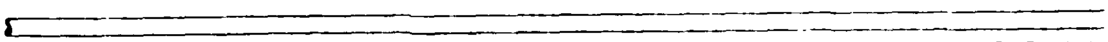

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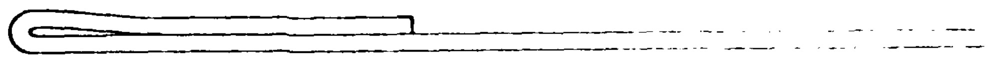

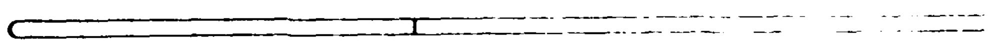

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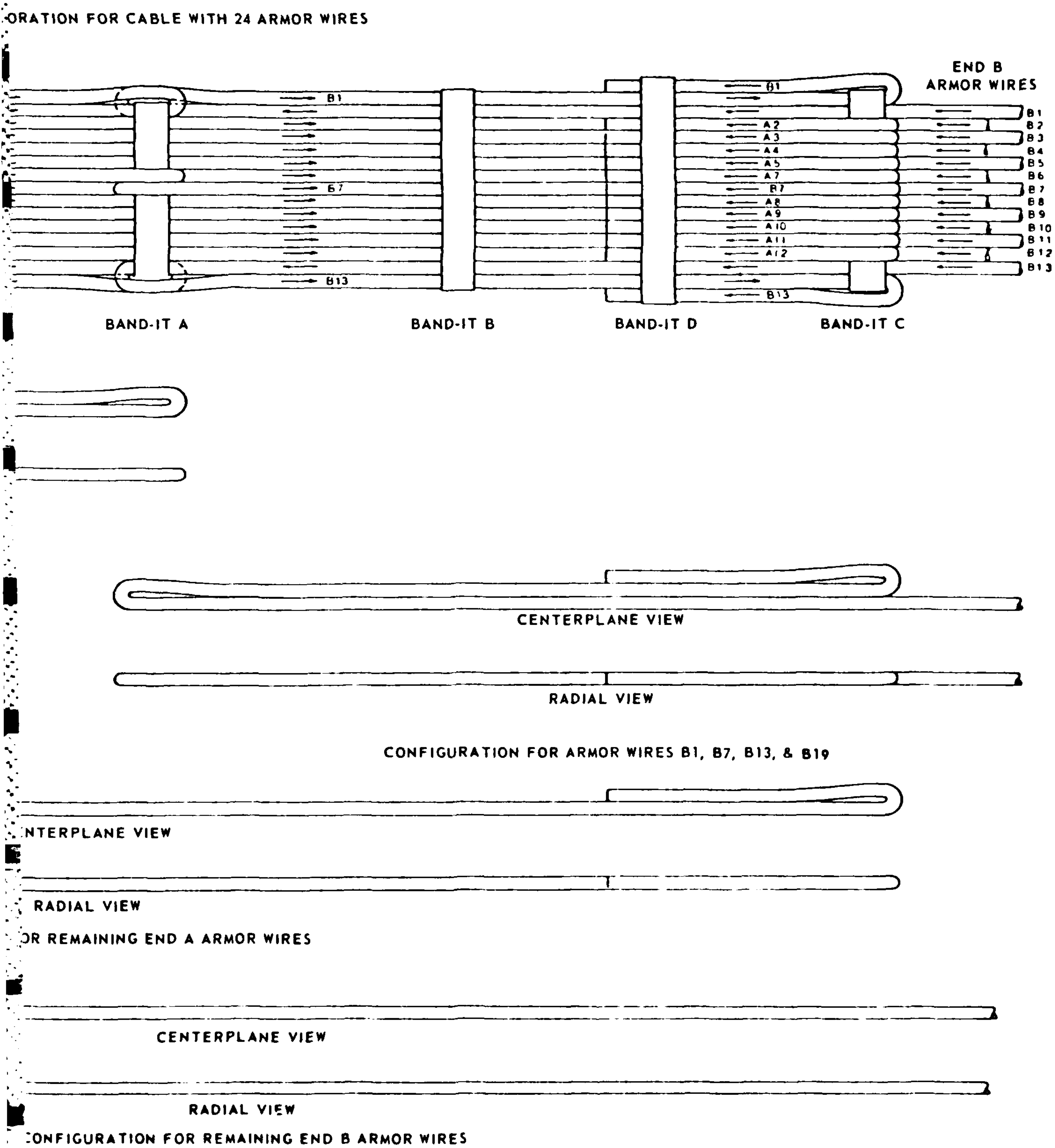


BAND-IT METHOD OF ARMOR RESTORATION

FIGURE 3

The way in which the outer jacket and the armor are stripped back from the cable ends prior to making the electrical splice is dependent upon the method of armor restoration that is to be employed. One method of armor restoration is detailed in Section 3.12.2 *"Armor splicing"* of MIL-C-15479C (SHIPS), Appendix A. Three other methods of restoring harbor defense cable armor in the field are given in this section of the splicing manual. Each of these methods is applicable to all five types of cable and therefore they are described prior to giving the details of performing the electrical splices. The three methods may be referred to as the Band-It method, the Crimp Sleeve method, and the Preformed Sector-Type Splice Rod method.

BAND-IT METHOD OF ARMOR RESTORATION

The final configuration of a Band-It type of armor restoration is depicted in Figure 3. Although 24 armor wires are illustrated in the cable shown, the method may be used with any of the harbor defense cables covered by this manual.

The tools and materials required both for initially preparing the cable ends for the splice and for the restoration of the armor after completion of the electrical splice, in the order first used, are as follows:

- Tape measure
- Knife
- Shoemakers' No. 6 thread-unwaxed
- Two hose clamps (outer jacket diameter)
- Screwdriver
- Hack saw
- Vise grip pliers
- Band-It clamp tool and 1/2 inch galvanized steel strap
- Mallet

It will be noted that in Figure 3 the cable end on the left has been designated End A and the cable end on the right has been designated End B. This convention will be followed in all of the text and illustrations in this manual. The corresponding armor wires are designated A1 through A24 and B1 through B24. It will also be assumed that each of the mating cables has initially been cut completely through the jackets, armor, and conductors, and that the cable ends are clean and square. The steps to be followed in the removal and restoration processes are indicated by the circled numbers below:

(1) Remove the outer jackets of Ends A and B. The lengths of jacket removed will be 26 inches for all five types of cable. Cut a nick in the outer jacket at the measured distance and then use the Shoemakers' thread to saw through the jacket all around the periphery down to the armor. Use the knife to slit the jackets and remove them.

(2) Screw a hose clamp over each jacket at the point where it has been cut off on End A and End B.

(3) Unwrap each of the armor wires and fold it back over the hose clamp out of the way.

(4) Measure back from the ends of the inner jacket the lengths indicated in Figure 4 and cut off the inner jacket and conductors at that point with the hack saw. The lengths to be cut off are:

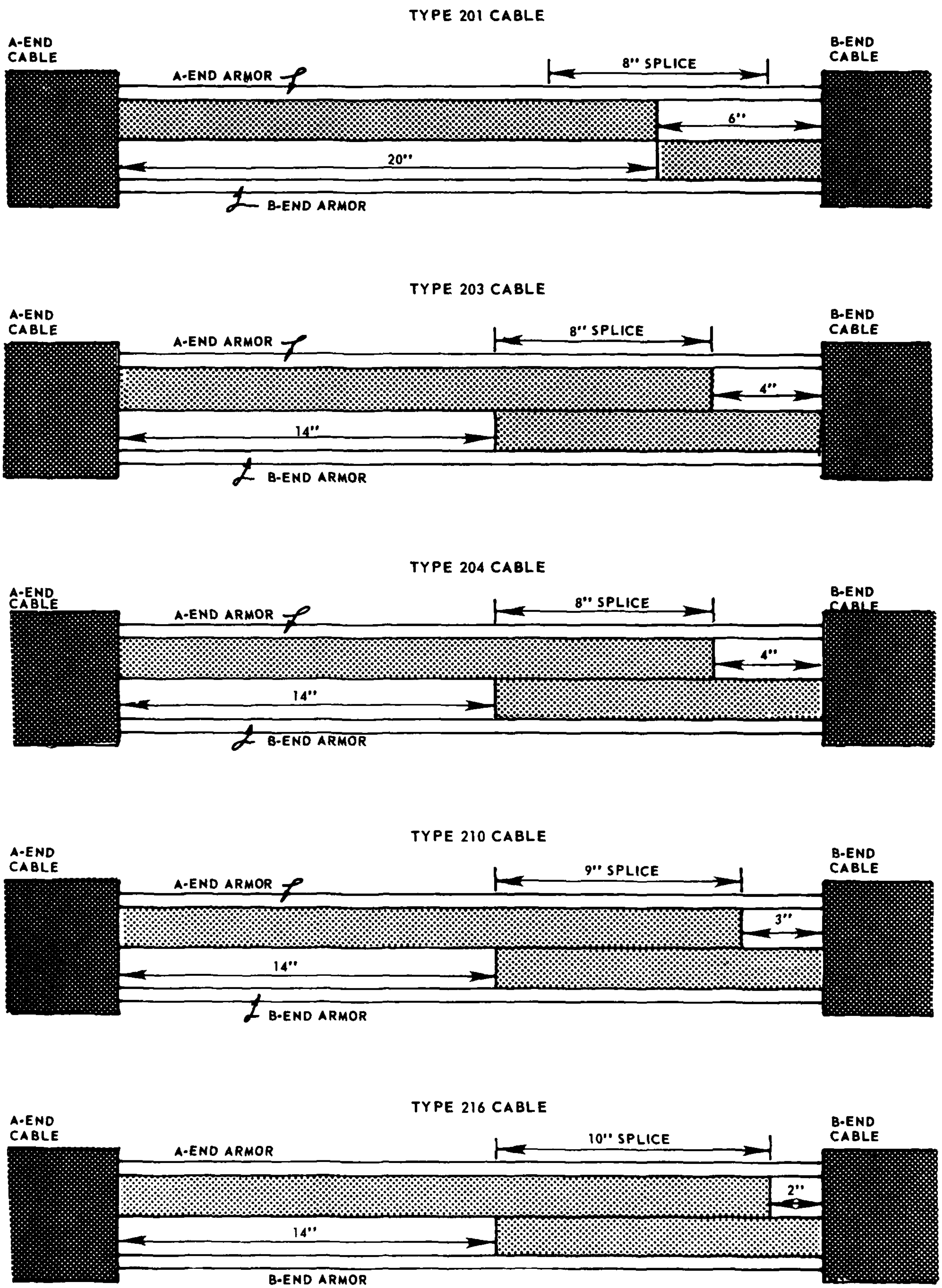
	Type 201	Type 203	Type 204	Type 210	Type 216
Cut off A-End inner jacket	6"	4"	4"	3"	2"
Cut off B-End inner jacket	20"	14"	14"	14"	14"

At this point the cable will be ready for the electrical splicing procedure described for each type of cable in following sections. Once the electrical splice has been completed, the restoration of the armor will follow the continuing steps below.

(5) Bend the armor wires from their folded back position and straighten each wire as it is laid down parallel to the cable. Straightening is accomplished by grasping the end of the wire with a pair of vise grips, applying tension, and twisting in a direction so as to unwind the helical formation of the wire. The straightened wires should extend approximately 1.7 inches beyond the hose clamps on either end of the cut-away outer jackets. The hose clamps should be 26 inches apart.

(6) Arrange the armor wires so that they are nested without any cross-overs and with the A-End wires alternating with the B-End wires. Install Band-It A (Figure 3) halfway between the two hose clamps and see that the armor wires are neatly bundled under it as the Band-It strap is tightened and cut off.

(7) Select four adjoining pairs of A-End and B-End armor wires that are approximately 90 degrees apart such that the Band-It tie buckle is halfway between two of the wire pairs. Bend each selected A-End wire back over Band-It A so that it is directed back toward the A-End cable. Then bend each B-End



CUT-BACK OF INNER JACKET ENDS FROM CABLE ENDS FOR BAND-IT RESTORATION

FIGURE 4

wire back over Band-It A so that it is directed back toward the B-End cable. Use the mallet to fold these wires in a tight bend around Band-It A and so that they lay in parallel with the other armor wires.

(8) Keeping the wires neatly bundled and without crossovers, install a Band-It B on each side of Band-It A, approximately 3 inches from the center. Then, moving another 6 inches toward the cable clamps at each end of the splice, install a Band-It C around the wire bundle. The Band-It C tie buckles should be on the opposite side of the cable from the Band-It A tie buckle.

(9) Working with one armor wire at a time, bend the wire back over each Band-It C leading toward the center of the splice and hammer into place with the mallet. The wires on each end should be laid parallel and evenly spaced. In the vicinity of the Band-It C tie buckle, the wires should be adjusted to pass around the buckle rather than over it.

(10) The shortest wires will be the four on each end that have been doubled back over Band-It A. Install Band-It D so that the edge toward the center of the splice just reaches the end of the shortest wire.

(11) Remove the two hose clamps and replace them with Band-It straps. This completes the Band-It method of armor restoration.

CRIMP SLEEVE CONNECTORS FOR ARMOR RESTORATION

The completed configuration of the crimp sleeve method of armor restoration consists simply of each pair of butted, straightened armor wires being connected together with a crimped connector sleeve which has the capability of equalling the strength of an uncut armor wire. Band-It straps are used along the length of the splice to keep the armor wire bundle together in an orderly fashion and equally dispersed around the splice inner jacket.

The tools and materials required both for initially preparing the cable ends and for the restoration of the armor after completion of the electrical splice, in the order first used are as follows:

- o Tape measure
- o Knife
- o Shoemakers' No. 6 thread-unwaxed
- o Two hose clamps (outer jacket diameter)

- Screwdriver
- Hack saw
- Vise grip pliers
- Bolt cutters or crimping tool with bolt cutter hole
- Nicopress crimp sleeves
- Nicopress crimping tool
- Band-It clamp tool and 1/2 inch galvanized tool strap
- Mallet

It will be assumed that each of the mating cables has initially been cut completely through the jackets, armor, and conductors, and that the cable ends are clean and square. The steps in the removal and restoration processes are indicated by the circled numbers below; for the restoration process, these numbers are matched with corresponding numbers on photographs of the operation, Figure 5.

1 Remove the outer jackets of Ends A and B. The lengths of jacket removed will be 26 inches for all five types of cable. Cut a nick in the outer jacket at the measured distance and then use the Shoemakers' thread to saw through the jacket all around the periphery down to the armor. Use the knife to slit the jackets and remove them.

2 Place a hose clamp over each jacket at the point where it has been cut off on End A and End B and tighten.

3 Unwrap each of the armor wires and fold it back over the hose clamp out of the way.

4 Measure back from the ends of the inner jacket the lengths indicated in Figure 4 and cut off the inner jacket and conductors at that point with the hack saw. The lengths to be cut off are:

	Type 201	Type 203	Type 204	Type 210	Type 216
Cut off A-End inner jacket	6"	4"	4"	3"	2"
Cut off B-End inner jacket	20"	14"	14"	14"	14"

At this point the cable will be ready for the electrical splicing procedure described for each type of cable in following sections. Once the electrical splice has been completed, the restoration of the armor will follow the continuing steps below.

ARMOR RESTORATION
CRIMP SLEEVE METHOD

FIGURE 5

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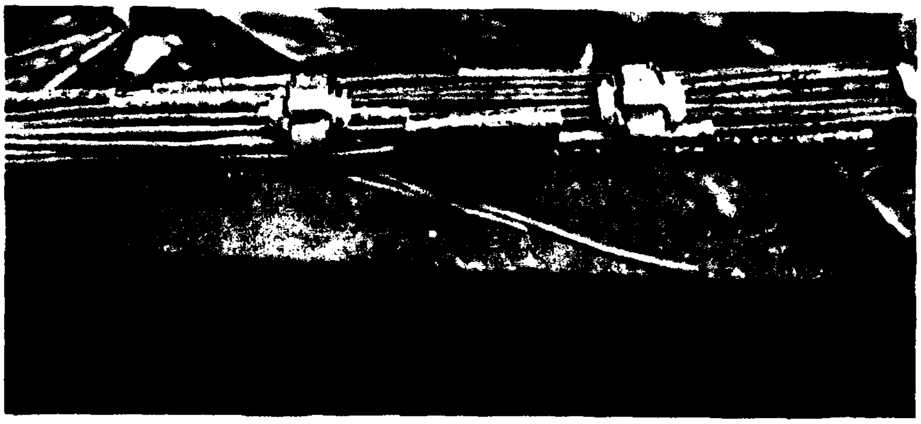

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(5) Bend the armor wires from their folded back position and straighten each wire as it is laid down parallel to the cable. Straightening is accomplished by grasping the end of the wire with a pair of vise grips, applying tension, and twisting in a direction so as to unwind the helical formation of the wire.

(6) Set the spliced cable in the vises so that there is a slight slack between the hose clamps. Pull one pair of armor wires taut and cut off so that the A-End and B-End wires just butt. Install a Nicopress crimp sleeve and crimp in three places on each side to the butting armor wires using the Nicopress crimping tool.

(7) Work around the armor bundle selecting adjoining wires from the A- and B-Ends; cut and connect together with butts staggered along the splice. Arrange the armor wires in a neat bundle around the spliced inner jacket and secure with Band-It straps on either side of the center of the open armor wires.

(8) Apply additional Band-It straps spaced 3 to 4 inches along the length of the splice section. Remove the hose clamps and replace with Band-It straps. This completes the armor restoration by the crimp sleeve method.

ARMOR RESTORATION USING PREFORMED SECTOR-TYPE SPLICE RODS

The preformed sector-type splice rods are galvanized steel wires of the same diameter as the armor wires. They are formed into a helix with a left-hand lay of 20 degrees and can be obtained in 80-inch lengths with an inside diameter equal to the outside diameter of the existing armor. Five rods, held together by the galvanizing, form a sector, but single preformed rods can also be obtained to fill in any gaps. The outside diameters of the armor of the harbor defense cables used in this manual were: Type 201-1.000 inches; Type 203-1.135 inches; Type 204-0.850 inches; Type 210-1.200 inches; Type 216-1.400 inches. However, the cable to be spliced should be measured before ordering the preformed splice rod sectors or individual splice rods.

The existing armor in the splice area can be cut off since no overlap of existing armor is required. The length of armor to be cut back is an equal amount on the A-End and on the B-End cables with the two cut off lengths totalling the sleeve length used over the splice. It is desirable to have the shrink sleeve covering the splice and at least one inch of the A-End and B-End inner jackets and to have the outside diameter of the sleeved joint equal to or less than the outside diameter of the cable armor. This provides for a smooth lay of the preformed splice rods. If, for some reason, the outside

diameter of the spliced area is greater than that of the cable armor, it is possible to obtain preformed sector-type splice rods that will accommodate a slight bulge in the center.

The tools and materials required both for initially preparing the cable ends for the splice and for the restoration of the armor after the completion of the electrical splice, in the order first used, are as follows:

- Tape measure
- Knife
- Shoemakers' No. 6 thread-unwaxed
- Two hose clamps (outer jacket diameter)
- Hack saw
- File
- Preformed Sector Type Splice Rods, 80"
- Preformed Single Splice Rods, 80"
- Mallet

The steps in the removal and restoration processes are indicated by the circled numbers that are also keyed in with the accompanying photographs of the operation, Figure 6.

1 Remove the outer jackets of Ends A and B. The lengths removed will be: Type 201-41 inches; Type 203 and Type 204-45 inches; Type 210-45 1/2 inches; Type 216-46 inches. Cut a nick in the outer jacket at the measured distance from each cable end and use the Shoemakers' thread to saw through the jacket down to the armor. Use a knife to slit the jackets and remove them.

2 Mark the armor wires at equal distances back from the A and B Ends of the cables. These lengths from the cable ends are: Type 201-7 inches; Types 203 and 204-9 inches; Type 210-10 1/2 inches; Type 216-11 inches. Apply a hose clamp around the armor at this point. Using a hack saw to cut most of the way through each armor wire, break the wires off one at a time.

3 File the ends smooth and square down to the inner jacket. At this point the cable will be ready for the electrical splicing procedure described for each type of cable in following sections. When the electrical splice has been completed, the armor restoration will follow the continuing steps below.

4 Set the electrically spliced cable up in the vises with a small amount of slack in the splice. Lay out one preformed section of splice rods so the

ARMOR RESTORATION
SECTOR-TYPE SPLICE RODS

FIGURE 6

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sector is centered between the cut-off ends of the outer jackets.

(5) Starting at the center, force the helicoidal sector to snap in place around the splice and the armor wire, working toward the two ends. Then center a second preformed splice rod sector and, again starting at the center, snap it into place around the splice and armor wire, keeping the two sectors as closely together as possible.

(6) Follow this with a third sector, again keeping the wires of mating sectors closely together.

(7) Work in the fourth sector into the armor wire splicing bundle. This may require some pounding with a mallet to work the sector into place. If any gaps remain it may be possible to work in a fifth sector or to use one or two additional preformed wires to complete the splicing operation. The total number of wires should equal or exceed the number of armor wires in the basic cable. This completes the preformed sector-type splice rod armor restoration.

TYPE 201 HARBOR DEFENSE CABLE SPLICING

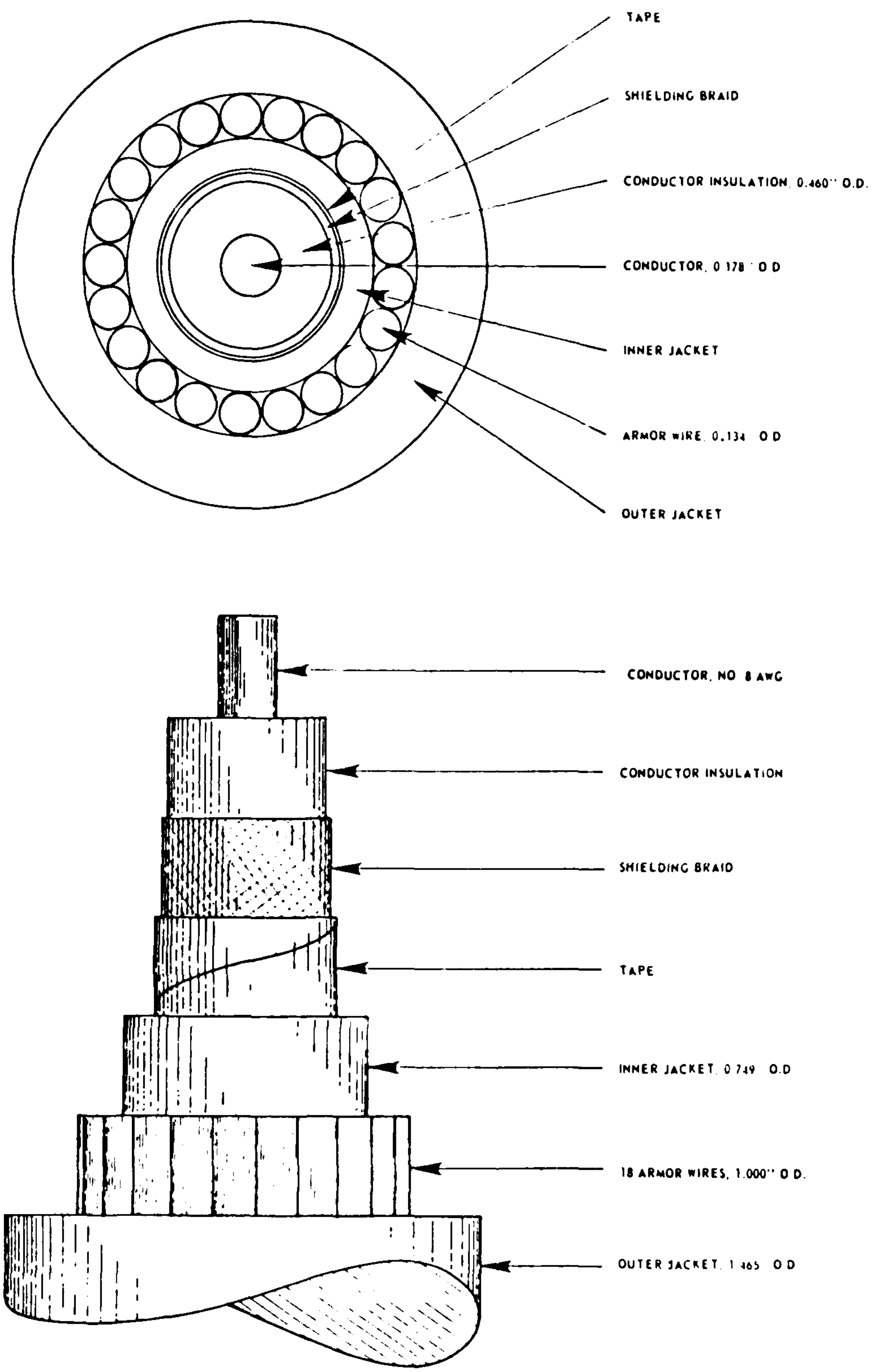
The Type 201 submarine cable used for harbor defense systems is a single conductor, coaxial, armored cable. The inner conductor is No. 8 AWG, 7 strand, untinned copper wire. As shown in Figure 7, the inner conductor is insulated with a dielectric material approximately 0.141 inches in thickness which, in turn, is surrounded by a shielding braid of No. 28 AWG untinned copper wire. The braid is wrapped with a mylar tape separating it from the inner jacket which is a type I synthetic resin; this inner jacket has an outside diameter of 0.749 inches.

Around the inner jacket are wrapped in a helical fashion 18 armor wires. These wires act as the strength member of the cable. Each of these galvanized steel wires has a tensile strength between 50,000 and 70,000 pounds per square inch and a diameter of 0.134 inches. The outside diameter of the armor layer is 1.000 inch. This, in turn, is surrounded by an outer jacket of type I synthetic resin with an overall outside diameter of 1.465 inches.

In splicing this cable it is important that there be complete electrical continuity in both the conductor splice and in the braid splice with continuous insulation between the two and with the radial separation maintained as constant as possible. This insulation must be free of air bubbles and completely watertight. The same requirements apply to the inner jacket splice material covering the shielding braid.

When joining the armor wires, the inner jacket and the materials contained therein should be slackened in such a way that any tensile loading will be taken up by the armor and not by the conducting or insulating elements. Watertight integrity is not essential outside the inner jacket, i.e., the outer jacket need not be replaced with a watertight seal between the two ends of the splice.

The splicing procedures given here for the Type 201 harbor defense cable and for Types 203, 204, 210, and 216 which follow, are concerned only with those components of the cable that are contained inside the spirally wrapped armor wires. The selected armor restoration method from those given previously will dictate how the outer jacket and the armor wires are removed prior to the electrical splice and how they are restored after the electrical splice.



TYPE 201 HARBOR DEFENSE CABLE

FIGURE 7

TOOLS AND MATERIALS REQUIRED

Before undertaking the splicing of the electrical elements of the cable the following tools and materials should be on hand. The tools, listed in the order of their first use during the splicing procedure, are as follows:

- Knife
- Scissors
- Shoemakers' No. 6 thread-unwaxed
- Small (1 1/2") paint brush
- Jacket cutting tool
- Long-nosed pliers
- Emery board
- Strip of emery cloth
- Crimping tool for #8-#10 wire size crimp
- Propane torch with soldering head attachment
- Hot air gun
- Soldering gun

Required materials, also listed in order of first use, are given below:

- Shrink sleeve, 2"-5/8", 14" long
- Trichloroethylene solvent
- Plastic electric tape, 3/4" width
- Crimp connector sleeves - 1 #8 wire size, 1 #10 wire size
- Solder paste
- Coreless solder wire
- Polyethylene irradiated tape, GE No. 210
- Tinned copper tape, 1", 3M No. 24
- Mastic tape

STEP-BY-STEP SPLICING PROCEDURE

Prior to starting the electrical splice, it will be presumed that on one of the mating cables the outer jacket has been cut back and the armor wires cut off or folded back so that there is sufficient length for sliding a 14-inch shrink sleeve over the inner jacket leaving the 7 inches required for the splice. On the mating cable, the outer jacket and armor will have

been cleared back leaving a length of at least 7 inches of the inner jacket clear for the splicing operation. Figure 8 illustrates the steps below.

1. Set the two cable ends up in vises on separated work benches. Clean the inner jacket shrink sleeve with solvent and slide it on to the long cable end to the point where it is out of the way. Nick one of the cables 4 inches back from the end.

2. Cut a length of Shoemakers' thread and use it to saw through the inner jacket down to the braid all around the periphery. Slide the cut end of the jacket off the braid. Apply the solvent with the paint brush to clean off any excess material from the inner jacket and from the braid.

3. After moving the cable ends in the vises to a good working position, use the same procedure as above on the other cable end. Apply two wraps of electrical tape around the braid contiguous to the cut off inner jacket. Then use the jacket cutting tool to cut the braid off each cable end leaving about 1 1/2 inches of braid from the inner jacket end. Nick the conductor insulation of each cable 1 inch back from the end and, using the Shoemakers' thread as a stripping tool, cut the insulation all around its periphery and slide off the insulation. Soak and brush the exposed conductor thoroughly to remove all mastic material from between the strands.

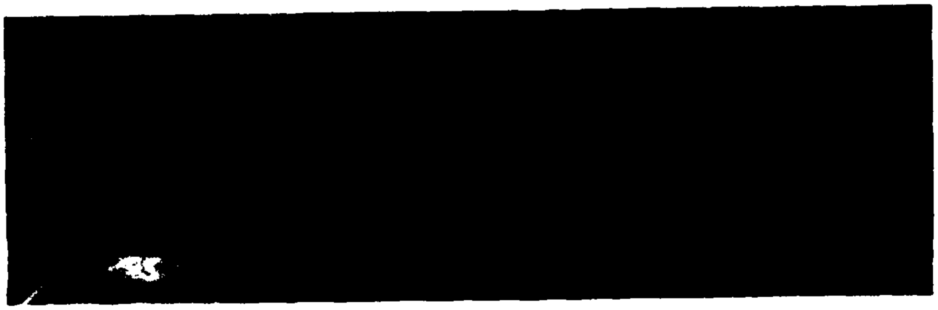
4. Round off the conductor ends with long-nosed pliers and check the fit of the #10 crimp sleeve. Although this is #8 wire, the smaller sleeve should go on with a good tight fit. If not, use the #8 crimp sleeve. Using a knife, pencil the insulation on the end of each cable.

5. Finish these tapers off with an emery board and round with a strip of emery cloth. The latter should also be used to roughen the inner jacket ends for about 1 inch back from the pencilled taper. Clean thoroughly with solvent.

6. Reset the vises so that the conductor ends are butting in the center of the crimp sleeve. With the small hole in the center of the crimp sleeve facing up, use the crimping tool to secure

TYPE 201 SPLICING

FIGURE 8A



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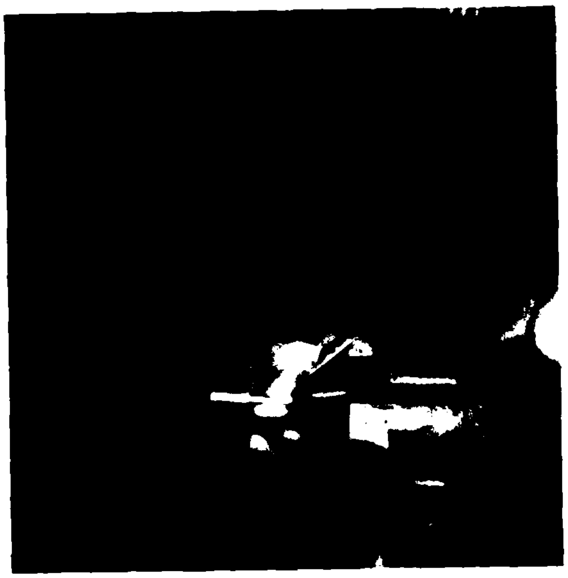

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the sleeve to each conductor end. The crimp should be made with the dimpled-in parts in line with the hole in the top of the sleeve. Then use the rounding notches in the crimping tool to round out the sleeve as much as possible.

7. Brush on solvert to clean joint thoroughly. Apply solder paste to hole in top of crimp sleeve and proceed to solder the joint. Since most soldering guns do not have adequate heating capacity for this size of crimp sleeve, it is recommended that a propane torch with a soldering head attachment be used. Tin the head to make good thermal contact with the bottom of the crimp sleeve and then feed the solder in through the hole in the top of the sleeve until it flows into the wire strands at the ends of the sleeve. Clean again with solvent after the joint cools.

8. Cut a length of the polyethylene irradiated tape, clean it with solvent, and start wrapping at the center of the splice. Using tight, half-lapped wraps, work up to the insulation taper on one end. Then start working back with another half-lapped layer to the taper at the opposite end of the splice. From this point, work back to the center, cut off the tape, and secure it with a touch of heat from a match or soldering gun. Brush clean with solvent.

9. Use the hot air gun to heat these first two layers of tape thoroughly, working all around the periphery. When the applied tape turns from milky white to transparent enough to see through to the crimp sleeve and wire, the heating can be stopped. Brush clean with solvent.

10. Apply the next two half-lapped layers of irradiated tape in the same manner, working a little farther up the taper of the pencilled insulation. Heat until transparent and clean again with solvent. This process should be continued until the overall diameter of the taped region is somewhat greater than the original insulation and extends over a length of about 3 1/2 inches.

TYPE 201 SPLICING

FIGURE 8B

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(11) At this point, a cutaway view of the splice shows the conductor and crimp sleeve completely contained within a hardened, insulating material that is securely fused to the conducter insulation of the connecting cables.

(12) Remove the electrical tape from the ends of the braid and brush off the entire length with solvent. Push back the braid on one end and start wrapping at the pushed back end with the tinned copper tape. This tape should be stretched out in wrapping so that it narrows down to half its unstretched width. Apply one half-lapped layer over the splice, running down to the pushed back braid on the other end, and then double back to the beginning end. Tack the two ends together with a small amount of solder and cut off the tape at this point.

(13) Pull the braid over the tinned copper tape on each end with solder paste dabbed on between the braid and tape. Using the solder gun, heat the braid until solder flows through the braid and makes a firm bond with the tape all around the periphery on both ends. Avoid overheating to prevent melting the insulation underneath. This completes the electrical connections.

(14) Wrap the splice with enough layers of mastic tape to build up to the thickness of the inner jacket. The splice is 8 inches long and the shrink sleeve is 14 inches long. Wrap two layers of mastic tape around the inner jacket, equally spaced from the splice, where the ends of the sleeve will fall in order to ensure a waterproof connection to the jacket of each cable end.

(15) Slide the shrink sleeve into place and begin heating with the hot air gun. Start in the center and heat until the sleeve shrinks down to the diameter of the mastic. Then start working gradually toward each end so that no air is entrapped within the splice.

(16) Finish heating the ends last so that a tight shrink is formed all along the sleeve and around the mastic tape at the ends. This completes the splicing of the Type 201 cable to the outside of the inner jacket. Armor restoration will be completed by one of the methods previously described.

TYPE 201 SPLICING

FIGURE 8C

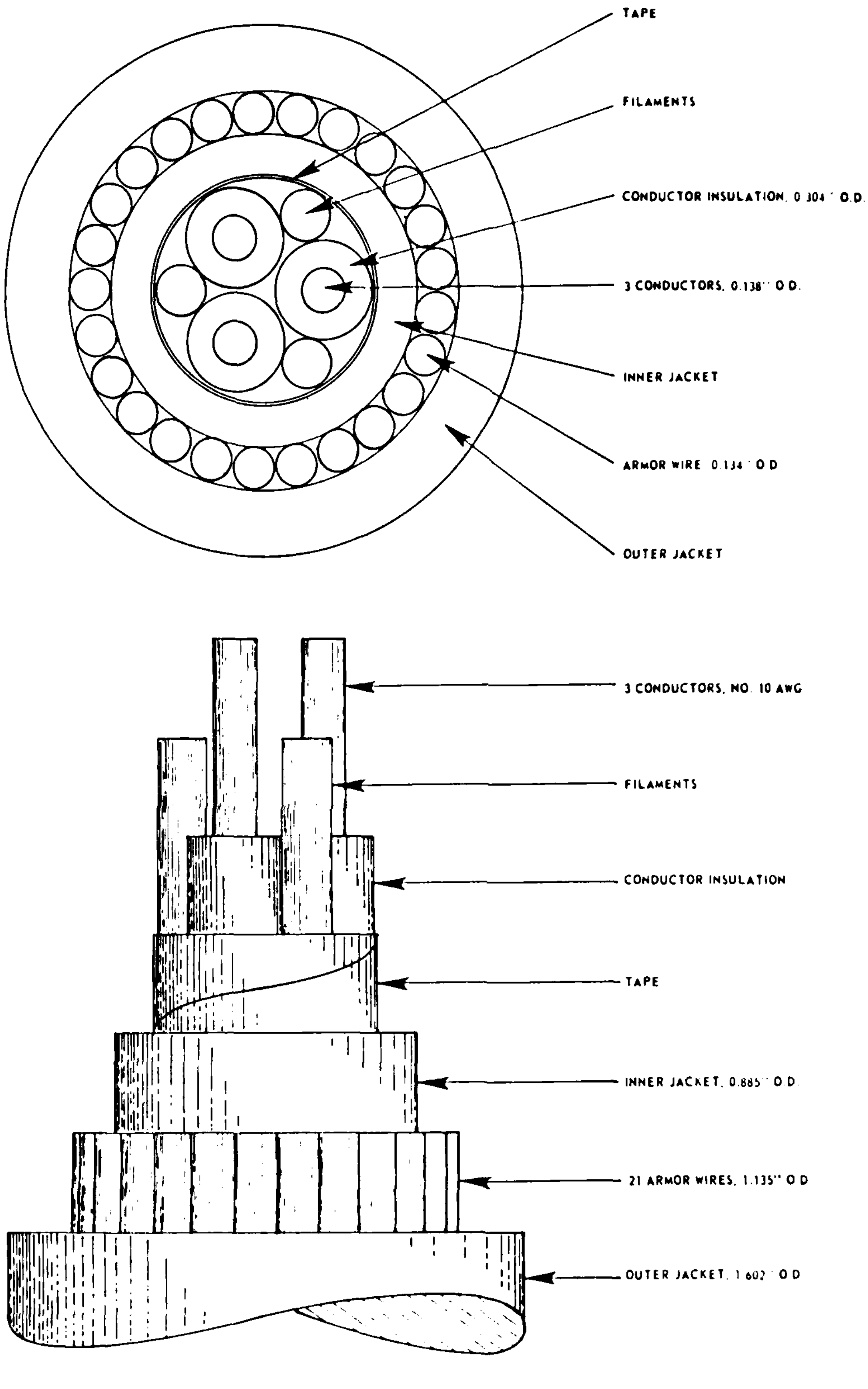
TYPE 203 HARBOR DEFENSE CABLE SPLICING

The Type 203 harbor defense cable used in inshore submarine installations is a three conductor cable that can be used either for power or communications. Each conductor is No. 10 AWG, 7 strand, untinned copper wire. As illustrated in Figure 9, each conductor is insulated with a dielectric material with a minimum wall thickness of 0.083 inches. The insulation colors are black, red, and white. These insulated conductors are cabled with three fillers or filaments to form a firm, well-rounded cross section. Mastic material can be included to fill the interstices of the core which is wrapped with mylar tape, separating it from the inner jacket which is a type I synthetic resin. The inner jacket has an outside diameter of 0.885 inches.

Around the inner jacket are wrapped 21 galvanized steel armor wires in a helical fashion to form the strength member of the cable. Each steel wire has a tensile strength between 50,000 and 70,000 pounds per square inch and a diamter of 0.134 inches. The outside diameter of the armor wire layer is 1.135 inches. Surrounding the armor wire is an outer jacket of type I synthetic resin with an overall outside diameter of 1.602 inches.

When splicing the cable there must be complete electrical continuity through each of the three conductors with no reduction in conductor cross section. Although it is desirable to connect the wires of common colored insulation, this may not always be possible since conductors at the cable ends to be spliced may be out of alignment. The conductor and insulation size is such that a crossover to maintain color continuity would distort the splice. In cases such as this, where the cable ends have reversed alignment, the convention is to connect black to black, red to white, and white to red. When this is done a notation should be made for later continuity checks.

Each conductor splice must be covered with a dielectric material of sufficient thickness to maintain equal or greater insulation resistance between conductors. This insulation must be free of air bubbles and completely watertight. For this three conductor cable, it is also desirable to continue the filaments through the splice to preserve the circular configuration, but filament ends need not be connected.



TYPE 203 HARBOR DEFENSE CABLE

FIGURE 9

The inner jacket must form a continuous watertight seal, free of internal air bubbles, between the inner jackets of the connecting cables. Its outside diameter should approximately equal that of the cable inner jackets.

When joining the armor wires by one of the methods previously described, the inner jacket and materials contained therein should be slackened to avoid any tensile loading within the inner core. Watertight integrity is not required outside the inner jacket and therefore no seal over the restored armor is necessary.

TOOLS AND MATERIALS REQUIRED

Before splicing the electrical elements of the Type 203 cable, the following tools and materials should be on hand. The tools and materials, listed in the order of their first use during the splicing procedure are:

Tools

- Knife
- Shoemakers' No. 6 thread-unwaxed
- Jacket cutting tool
- Small (1 1/2") paint brush
- Scissors
- Diagonal wire cutters
- Wire stripper (No. 10 wire)
- Pencilling tool
- Long-nosed pliers
- Emery Board
- Strip of emery cloth
- Stiff 1/2" brush
- Crimping tool for #10 wire
- Pipe cleaner
- Soldering gun
- Hot air gun

Materials

- Shrink sleeve, 2"-5/8", 10" long
- Trichloroethylene solvent
- Paper towels
- Masking tape
- Crimp connector sleeves for No. 10 wire
- Shrink sleeve tubing, 12 mm I.D., 6" long
- Solder paste
- Coreless solder wire
- Polyethylene irradiated tape, GE No. 210
- Mastic tape

STEP-BY-STEP SPLICING PROCEDURE

Before the electric splice is started, the outer jacket on one of the mating cables should have been cut back and the armor wires cut off or folded

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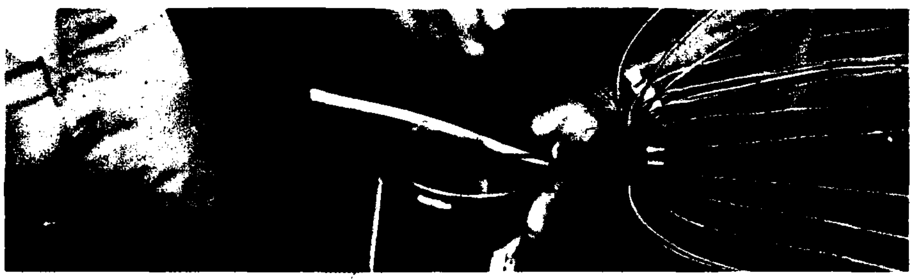

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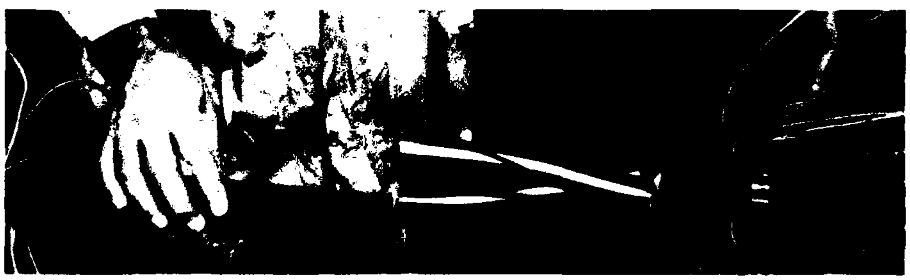

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TYPE 203 SPLICING

FIGURE 10A

back leaving sufficient length for sliding a 10-inch shrink sleeve over the inner jacket leaving the 8 inches required for the splice and room to clamp the inner jacket in a vise without clamping the sleeve. On the mating cable, the outer jacket and armor will have been cleared back leaving at least 8 inches of the inner jacket clear for the splicing operation, Figure 10.

1. Set the two cable ends up in vises on separated work benches. Clean the inner jacket shrink sleeve with solvent and slide it on the long cable end to the point where it is clear of the splice area and the vise. Nick one of the cables 8 inches back from the end and saw through to the tape with the Shoemakers' thread. Use a new length of thread for each cutting operation as it loses its cutting capability after one or two cuts.

2. Use the jacket cutting tool to split the jacket back to the cut and remove the inner jacket.

3. Soak the mylar tape thoroughly with the solvent and paint brush and then remove the tape back to the point where the inner jacket is cut off. Cut the tape at this point with scissors.

4. Clean the mastic from the insulated conductors and the filaments using brushed-on solvent and paper towels to ensure complete removal of all mastic. Solvent that is contaminated with the mastic should be replaced.

5. Follow the same procedure on the end of the mating cable and then clamp the two cables in place so that the exposed 8 inches to the two sets of conductors completely overlap. Be sure that the shrink sleeve is on the cable.

6. Bend the three filaments on each of the mating cables back over the jackets and secure them out of the way with masking tape.

7. Use the diagonal wire cutters to cut the mating pair of black wires so that they will butt together.

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TYPE 203 SPLICING

FIGURE 10B

8 In the splice illustrated, the cables were mismatched so that it was necessary to splice white to red and red to white. Cut the matching wires so that the butts are staggered 2 inches apart.

9 Measure half the crimp sleeve length and strip the required amount of insulation from the end of each of the six conductor wires.

10 Use a pencilling tool or a knife to taper the ends of the cut back insulation. Then use a pair of long nose pliers to reshape the conductor ends where necessary due to cutting with the diagonal wire cutters.

11 With an emery board or emery cloth, roughen the insulation on each conductor about 1 inch back from each taper. Then clean the insulation thoroughly with the solvent. Using a small, stiff brush, scrub each conductor end to remove any mastic that may remain between the strands of wire.

12 Use the crimping tool to apply the crimp connecting sleeves to the conductors on one of the mating cable ends, arranging crimp sleeves with center slot hole on top. Dimple in from top and then round crimp sleeve. Cut three 2-inch lengths of shrink sleeve tubing and soak thoroughly in solvent and clean inside with a pipe cleaner. Next, slide the shrink sleeves on the long ends of the three conductors and then crimp the other ends of the crimp sleeves to the mating conductors.

13 Dab soldering paste into the slot on one crimp sleeve. Tin the soldering gun tip and heat the crimp sleeve until the solder will flow into the hole to fill the crimp joint. Avoid melting insulation back from ends of crimp sleeve. Use the same technique to solder the other two crimp connections.

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TYPE 203 SPLICING

FIGURE 10C

14 Cut a length of the polyethylene irradiated tape and clean with solvent. Starting in the center of one crimp sleeve, wrap tightly with half laps working to the right to a point about one-half inch over the end of the insulation. Then, continuing with half laps work to the left across the crimp sleeve to a point one-half inch over the end of the insulation on the mating conductor. Then wrap with half laps back to the center. Cut off tape with scissors and use match or soldering gun to heat end and press to hold in place.

15 Cover the other two conductors with a wet cloth and use the hot air gun to tighten the tape around the joint, working the gun on all sides of the tape. When the taped area turns from milky white to clear plastic, it has had sufficient heat. Clean off another strip of irradiated tape with a towel soaked in solvent and apply it to the same joints, again using two half-lapped layers. Heat again with the hot air gun until the tape turns clear. Follow the same procedure on the other two conductor connectors.

16 Clean all three joints again with the solvent before sliding the shrink sleeves over the solidified irradiated tape. The shrink sleeve ends should not overlap. Again, cover two conductors with a wet cloth and start heating the shrink sleeve on the third conductor with the hot air gun. Apply the heat from all directions until the shrink sleeve forms a tight seal. This can be determined when the insulation at each end bulges slightly. Repeat with the other two conductors.

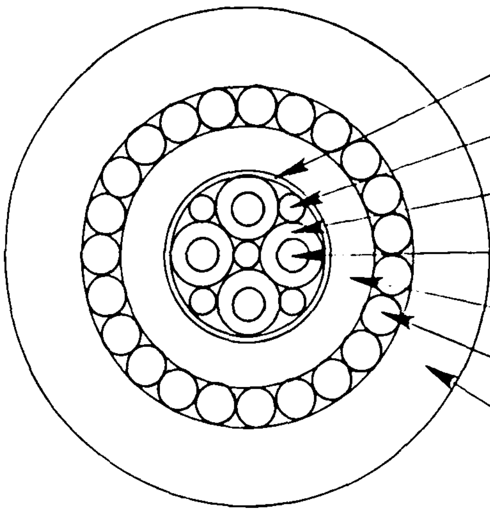
17 Move the support tables apart (or change position of cable in vises) to pull the joint taut. Wrap with one half-lapped layer of mastic tape. Then remove the masking tape and lay in the three filaments from each end to fill out the splice. Cover these with another half-lapped layer of mastic tape extending one inch on either side of the slice.

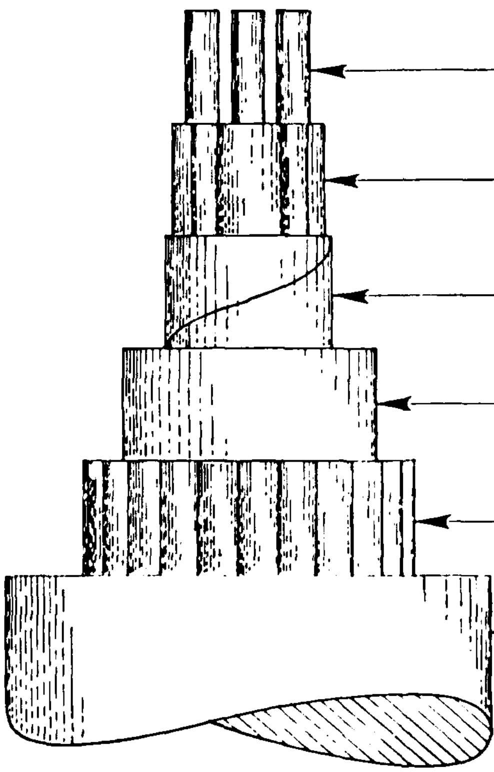
(18) Slide the jacket shrink sleeve over the mastic tape. Using the hot air gun, start heating in the center of the sleeve, working around it and then working gradually out to the ends until the sleeve fits tightly over the entire splice and provides a watertight connection between the inner jackets of the spliced cables. This completes the splicing of the Type 203 cable to the outside of the inner jacket. Armor restoration will be completed by one of the methods previously described.

TYPE 204 HARBOR DEFENSE CABLE SPLICING

Type 204 harbor defense system submarine cable is a four conductor armored cable. The four conductors are No. 14 AWG, 7 strand, untinned copper wire, each 0.0253 inches in diameter. As shown in Figure 11, each conductor is insulated with a dielectric material approximately 0.043 inches in wall thickness. The latest specifications call for this insulation to be color coded black, white, red, and green. However, for older cables the color coding may vary. (The cable illustrated in this manual was black, brown, red, and green.) These insulated conductors may or may not be cabled with four or five fillers or filaments depending upon the manufacturer. Mastic material may be included to fill the interstices and the cable/filament/mastic core is wrapped with mylar tape to separate it from the inner jacket. The inner jacket is of type I synthetic resin and has an outside diamter of 0.655 inches.

The strength member of the cable comprises a layer of 17 armor wires, each 0.109 inches in diameter, with an outside diameter of the armor layer of 0.850 inches. The galvanized steel armor wires have a tensile strength of 50,000 to 70,000 pounds per square inch but, since this cable has fewer armor wires of lesser diameter than the other harbor defense cables, it has a considerably lower breaking strength although its flexibility is greater. Surrounding the armor wire is an outer jacket of type I synthetic resin with an overall outside diameter of 1.321 inches.





TYPE 204 HARBOR DEFENSE CABLE

FIGURE 11

When splicing the cable there must be complete electrical continuity through each of the four conductors with no reduction in conductor cross section at the splice. In this cable it is essential that conductors with like colored insulation be connected together except in the case of an old and new cable where brown can be spliced to white. This change, however, should be noted for later continuity checks.

The dielectric material covering each conductor splice must be of adequate thickness to maintain equal or greater insulation resistance between conductors than in the unspliced cable. The dielectric material must be completely watertight between the insulation on mating cables and must be free of any air cavities. Continuation of filaments or fillers through the splice is not required.

The inner jacket splice material must form a continuous watertight seal, free of internal air bubbles, between the inner jackets of the connecting cables and its outside diameter should approximate that of the cable inner jacket.

When joining the armor wires by one of the methods previously described, the inner jacket and materials contained therein should be slackened to avoid any tensile loading within the inner core. Watertight integrity is not required outside the inner jacket and therefore no seal over the restored armor is necessary.

TOOLS AND MATERIALS REQUIRED

Before splicing the electricl elements of the Type 204 cable, the following tools and materials should be on hand. The tools, listed in the order of their first use during the splicing procedure, are as follows:

- Small (1 1/2") paint brush
- Knife
- Shoemakers' No. 6 thread-unwaxed
- Jacket cutting tool
- Diagonal wire cutters

- o Wire strippers for No. 14 wire
- o Long nosed pliers
- o Pencilling tool
- o Emery board
- o Strip of emery cloth
- o Stiff (1/2") brush
- o Scissors
- o Pipe cleaner
- o Crimping tool
- o Soldering gun
- o Hot air gun

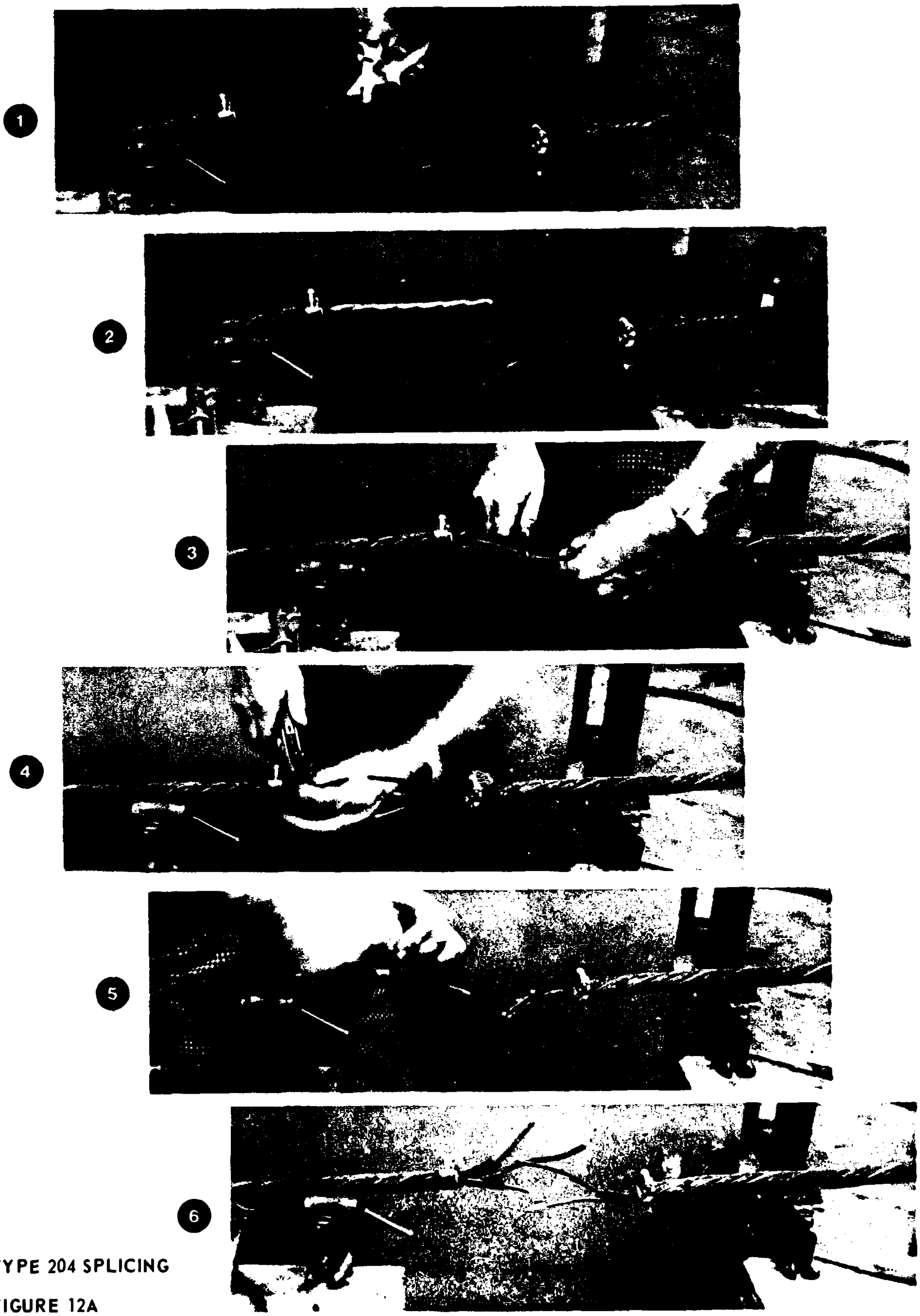
Required materials, also listed in order of first use, are given below:

- o Shrink sleeve 2"-5/8", 10" long
- o Trichloroethylene solvent
- o Paper towels
- o Masking tape
- o Shrink sleeve tubing, 8 mm I.D., 6" long
- o Crimp connector sleeves for No. 14 wire
- o Solder paste
- o Coreless solder wire

STEP-BY-STEP SPLICING PROCEDURE

Before the electrical splice is started, the outer jacket on one of the mating cables should have been cut back and the armor wires cut off or folded back leaving sufficient length for sliding a 10-inch shrink sleeve over the inner jacket leaving the 8 inches required for the splice and room to clamp the inner jacket in a vise without clamping the sleeve. On the mating cable the outer jacket and armor will have been cut back leaving at least 8 inches of the inner jacket clear for the splicing operation.

In the photographs for this splicing operation, it will be noted that the outer jacket has been cut well back out of the way but that the armor has been cut off just clear of the splice and is held in place by hose clamps. This was done so that this cable could be used to illustrate the preformed splice rod method of armor restoration described earlier. Also, an internally tarred shrink sleeve is to be used to replace the inner jacket over the splice. With the armor wires cut off, this shrink sleeve could slide down over the armor wires and was clear of the early pictures of Figure 12.



TYPE 204 SPLICING

FIGURE 12A

1. Clean the shrink sleeve with solvent and slide it over the long end of the cable. Set up the two cable ends in vises on separated work benches. Nick one of the cables with a knife 8 inches back from the end and saw through to the tape with the Shoemakers' thread. Use the jacket cutting tool to split the inner jacket and remove. Then, strip off the mylar tape.

2. In a similar manner, cut and strip off the inner jacket on the mating cable 8 inches back from the end. Care should be taken not to cut through the tape with either the cutting thread or the jacket cutting tool.

3. Using solvent and a paper towel, clean all mastic or other material from the conductor insulation. If filaments are incorporated, fold them out of the way and secure with masking tape. Move the tables, or the cable in the vises, to overlap the mating conductors for their full 8-inch length. With the diagonals, cut the mating pairs of like colored conductors so that the butted ends will be staggered along the splice.

4. With the wire strippers set for No. 14 wire, strip the end of each conductor back half the length of the crimp connection sleeves. With long nosed pliers, round the ends of the conductors where the diagonal cut was made.

5. Use a pencilling tool to taper the end of the insulation on each of the eight conductors. Then with an emery board or strip of emery cloth, roughen the insulation on each conductor about one inch back from the end. Clean thoroughly with solvent using a stiff brush on the conductor wires with the wires immersed in the solvent to remove all material from between the strands.

6. Cut the 10 mm shrink sleeve tubing into 1 1/2 inch lengths. Soak in solvent and clean internally with pipe cleaner. Slide on to longer end of the four conductors.

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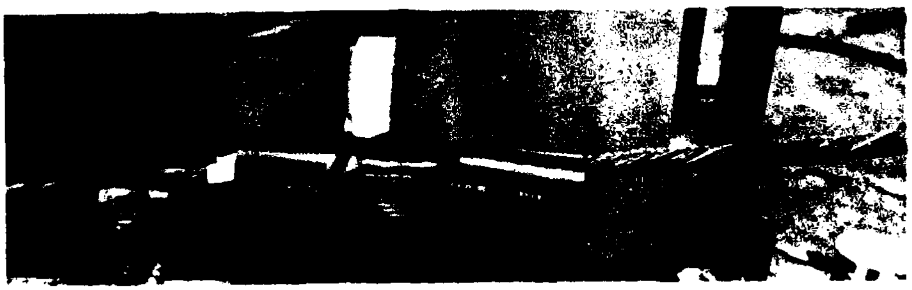


TYPE 204 SPLICING

FIGURE 12B

7. Close down the distance between inner jacket ends and install the crimp sleeves to connect the four conductors with matching colors. The crimp sleeves should have the slot in the center on top and the tool used to dimple down from the top. Then use the crimping tool to round the crimp sleeves.

8. Apply a dab of solder paste to the slot in each crimp sleeve and solder all four sleeves to the conductor wires. Clean all conductors thoroughly with solvent and wash hands before working with polyethylene irradiated tape.

9. Cut four lengths of the irradiated polyethylene tape and clean each with solvent and a paper towel. Starting from the center of one crimp sleeve, apply two half-lapped layers of tape extending 1/2 inch over the insulation on either side, and heat seal the end. Covering the other three conductors with a wet cloth, heat the joint with the hot air gun until the tape turns from milky white to clear. Repeat for the other three conductors.

10. After cleaning again with solvent, slide a shrink sleeve over one conductor splice and cover the remaining conductors with a wet cloth. Use the hot air gun to tighten the sleeve over the joint until the insulation bulges on either side. Repeat this operation for the remainder of the conductors.

11. If filaments are present, remove the masking tape and lay them back into the spliced area. Wrap with enough half-lapped layers of mastic tape to build up to the diameter of the inner jacket. In the illustration the hose clamps at the end of the armor are being removed for application of the shrink sleeve.

12. Mark the shrink sleeve ending point with masking tape, slide the sleeve into place, and start heating with the hot air gun working from the center out toward each end. In the case shown, a 12-inch tar-lined polyolefin sleeve is used extending over the cut-off ends of the armor. Armor restoration will be completed, in this case, using the preformed, sector type splice rods described earlier.

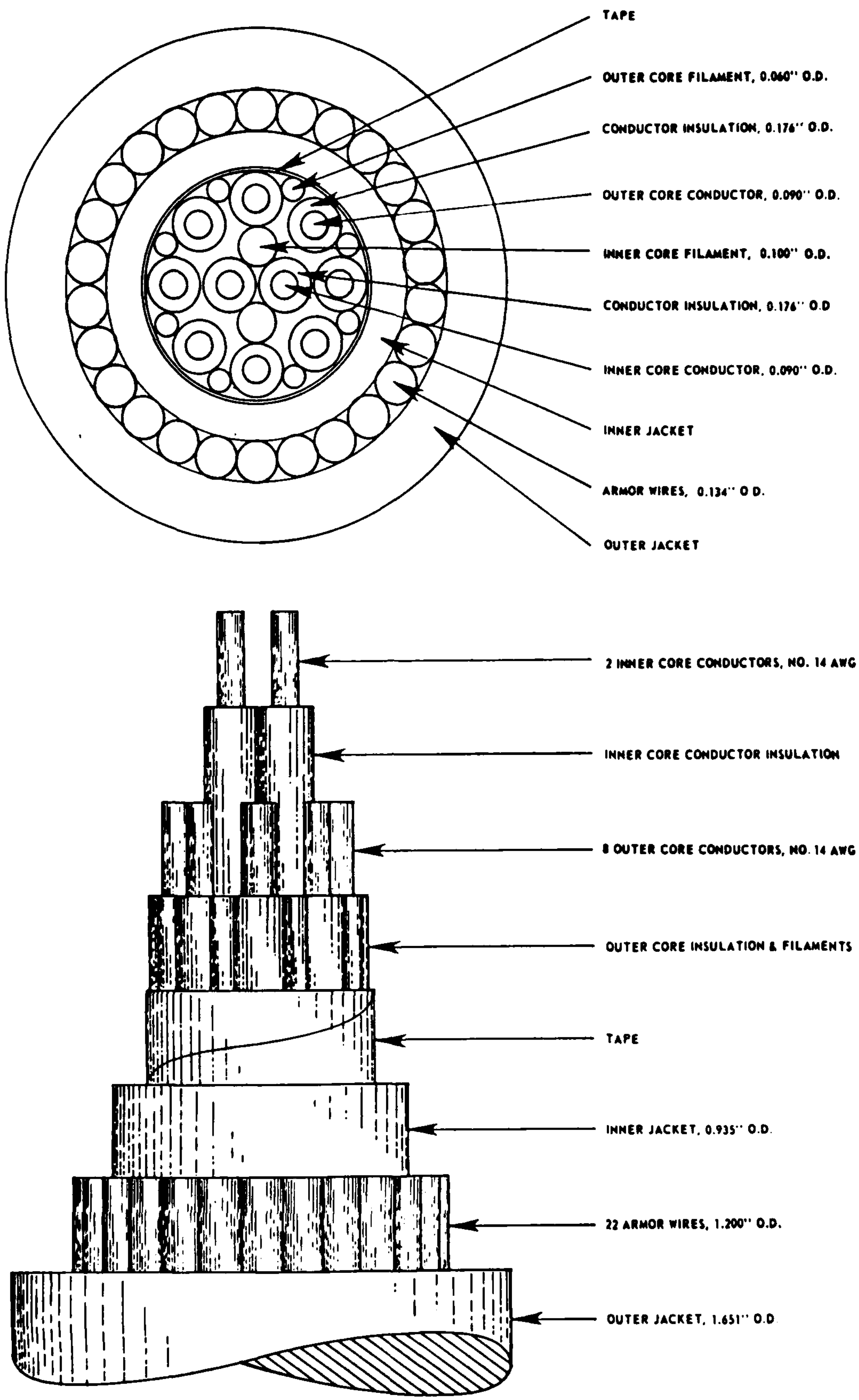
TYPE 210 HARBOR DEFENSE CABLE SPLICING

Harbor defense cable Type 210, is a ten conductor armored submarine cable with an inner core of two conductors and an outer core of eight conductors. All ten conductors are No. 14, 7 strand, untinned copper wire. Each strand is 0.0253 inches in diameter. As shown in Figure 13, each conductor is insulated with dielectric material, 0.043 inches in thickness. The two inner core conductors are laid up spirally with at least two filaments of 0.100 inches diameter. These inner core conductors are color coded white and black.

The inner core is surrounded by an outer core of eight conductors cabled with filaments 0.060 inches in diameter. The latest specification calls for these outer core conductors to be color coded red, green, yellow, brown, blue, orange, gray, and purple in clockwise rotation. However, in the older cable used for preparing the splice shown in this manual, the outer core conductor colors were red, blue, green, and orange interspersed with four black insulated conductors. The specification also calls for the outer core to be wrapped with mylar tape, which was not included in the older cable. The inner jacket, surrounding the outer core, is of type I synthetic resin and has an outside diameter of 0.935 inches.

The strength member of the cable is made up of a bundle of 22 armor wires, each 0.134 inches in diameter, wrapped in a helical fashion around the inner jacket. The outside diameter of the armor bundle is 1.200 inches. Each galvanized steel armor wire has a tensile strength between 50,000 and 70,000 pounds per square inch and a diameter of 0.134 inches. Surrounding the armor wire is an outer jacket of type I synthetic resin with an overall diameter of 1.651 inches.

When splicing the cable there must be complete electrical continuity through each of the ten conductors with no reduction in conductor cross section. It is essential that connections be made between wires of common colored insulation. This may be a particular problem if older cable is used with five black insulated conductors or if a newer cable is spliced to an older cable. In either such case, the matching should be done so that the two inner core black conductors are connected together. In the outer core, the colored conductors should be connected first, and then the black to black or the black to color match should be made to follow the same pattern around



TYPE 210 HARBOR DEFENSE CABLE

FIGURE 13

the conductors of the outer core. The connections should be carefully recorded for each splice for use in later continuity checks.

Each conductor splice must be covered with a dielectric material of sufficient thickness to maintain equal or greater insulation resistance between conductors. This dielectric must be free of air bubbles and must form a watertight connection between the insulation on matching cables. For this ten conductor cable it is not necessary to continue the filaments through the splice so they can be cut off at the time the inner jacket is removed.

TOOLS AND MATERIALS REQUIRED

Before splicing the electrical elements of the Type 210 cable, the following tools and materials should be on hand. Listed in order of their first use during the splicing procedure, these are:

Tools

- o Knife
- o Shoemakers' No. 6 thread-unwaxed
- o Jacket cutting tool
- o Scissors
- o Small (1 1/2") paint brush
- o Pipe cleaner
- o Diagonal wire cutters
- o Long nosed pliers
- o Pencilling tool
- o Crimping tool for No. 14 wire
- o Emery board
- o Strip of emery cloth
- o Soldering gun
- o Hot air gun
- o Propane torch

Materials

- o Trichloroethylene solvent
- o Paper towels
- o Shrink sleeve, 2"-5/8", 12" long
- o Shrink sleeve tubing, 8 mm I.D., 15" long
- o Crimp connector sleeves for No. 14 wire
- o Solder paste
- o Coreless solder wire
- o Polyethylene irradiated tape, GE No. 210

STEP-BY-STEP SPLICING PROCEDURE

Prior to starting the electrical splice, the outer jacket on one of the mating cables should have been cut back and the armor wires cut off or folded back leaving sufficient length for sliding a 12-inch shrink sleeve over the inner jacket leaving the 9 inches required for the splice and room to clamp the inner jacket in a vise without clamping the sleeve. On the mating cable, the outer jacket and cable will have been cleared back leaving at least 9 inches of the inner jacket clear for the splicing operation. See Figure 14.

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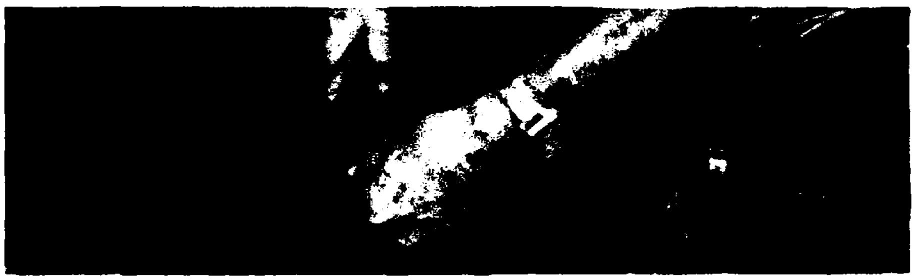

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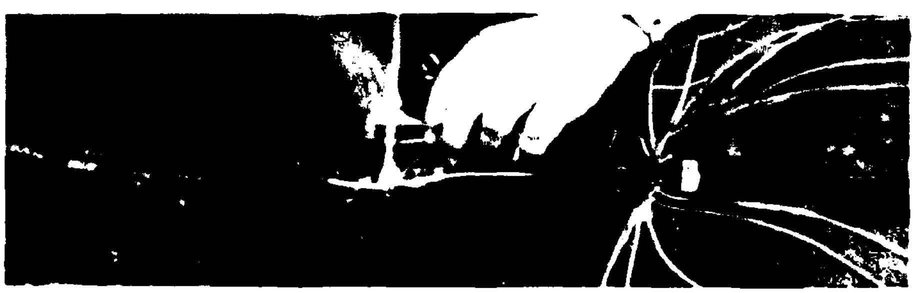

TYPE 210 SPLICING

FIGURE 14A

1. Set the cable end with the longer stripped inner jacket in a vise. Nick the inner jacket with a knife 9 inches back from the end and saw through the jacket with the Shoemakers' thread. Use extreme care not to cut cable insulation if there is no tape around core. Use jacket cutting tool to split jacket.

2. Remove jacket from conductors. Remove tape and clean off mastic on conductors with solvent and paper towels. Follow same procedure on mating cable and set up in vise so that conductors overlap for full 9 inches of the splice length.

3. Clean large shrink sleeve with solvent and slide over inner jacket. Cut shrink sleeve tubing into 1 1/2 inch lengths; clean inside and out with pipe cleaners and solvent. Cut matching colored wires with staggered butts along splice length, strip and round ends for crimp sleeves and taper insulation with pencilling tool. Slide shrink sleeve on long end and use crimping tool to secure crimp sleeve on one end.

4. For each colored wire pair, proceed to apply crimp sleeves with sleeve slot up; dimple down and round sleeve with crimping tool. Taking the black wires, starting with the inner core wire, cut off, round, slide on shrink sleeves, and install crimp sleeves, making sure that either black to black or black to color are in the proper sequence. Roughen all conductor insulation one inch from crimp with emery board or strip of emery cloth.

5. Clean all wires, crimp sleeves, and shrink sleeves with solvent. Recheck all wires to make sure that connections are proper and shrink sleeves in place. Make notations as to order in which pairs are matched and make electrical resistance check through cable if possible.

6. Apply a dab of solder paste to the slot on top of one crimp sleeve. Tin the soldering gun tip and heat the crimp sleeve from the under side. Feed in solder wire through the slot until it flows through the crimp sleeve and the wire. Repeat for remaining nine conductors.

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TYPE 210 SPLICING

FIGURE 14B

7 Wash hands. Cut ten lengths of polyethylene irradiated tape and clean with solvent and paper towel. Wrap two half-lapped layers of tape around each crimp sleeve extending over taper to conductor insulation on each side; seal end with heat and cut off excess tape. Repeat for all conductors.

8 Wrap wet cloth around all but one conductor. Heat irradiated polyethylene tape with hot air gun until tape turns from milky white to transparent. Repeat process for each of nine remaining conductors. Wash all conductors with solvent.

9 Slide shrink sleeves over irradiated tape and heat each individually with hot air gun. Each sleeve should shrink down until insulation bulges slightly on either end. Be sure that only one conductor is heated at a time.

10 In the case shown, a polyolefin, tar-lined shrink sleeve was used which is 12-inches long, extending 1 1/2 inches over the inner jacket at each end of the splice. This was heated with a propane torch, starting at the center and working toward the two ends.

11 As the tar-lined shrink sleeve shrinks down around the conductors, the tar works its way in between the conductors to completely fill the splice with a solid but flexible material. This makes it unnecessary to wrap the conductors with a mastic prior to applying the shrink sleeve. Also, the excess tar works its way to the ends of the sleeve and forms a tight seal around the inner jackets. This completes the splicing of the Type 210 cable to the outside of the inner jacket. Armor restoration will be completed by one of the methods described earlier.

TYPE 216 HARBOR DEFENSE CABLE SPLICING

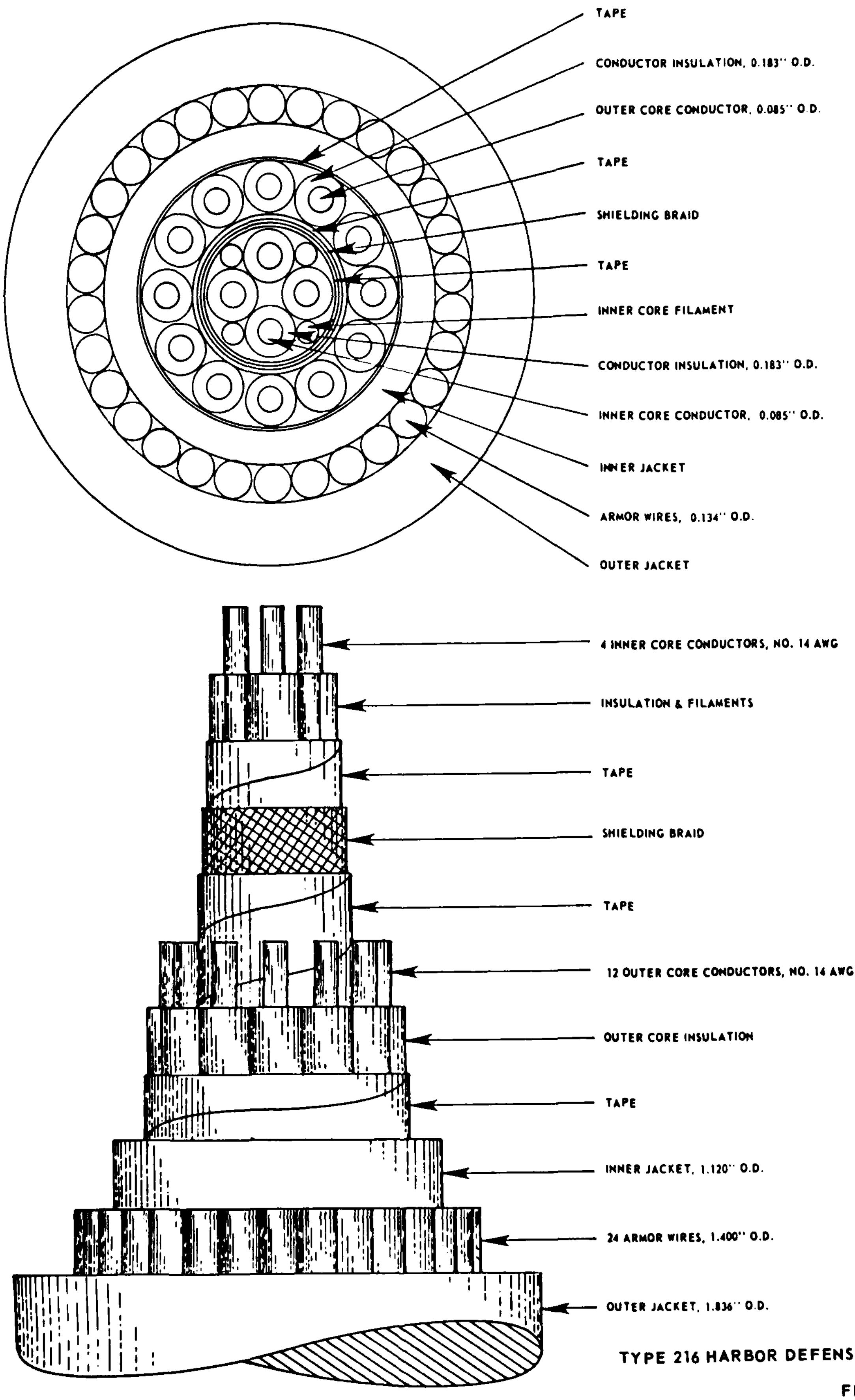
Harbor defense cable Type 216 is an armored main hydrophone cable with sixteen conductors. It has an inner core of four conductors inside a shielding braid around which are dispersed twelve outer core conductors. All sixteen conductors are No. 14, 7 strand, untinned copper wire with each strand 0.0253 inches in diameter. Figure 15, shows each conductor to be insulated with a dielectric material, with a minimum wall thickness of 0.049 inches. The four inner core conductors are color coded, according to the specifications - black, white, red, and green. However, in the older cable used for splicing the white was replaced with brown.

A mylar tape surrounds the inner core and over the tape is a shielding braid of No. 28 AWG untinned copper wire with a braid angle of 35 degrees and a minimum coverage of 88 percent. Over the braid is another layer of mylar tape around which are specially laid twelve insulated outer conductors. The insulation on these conductors is color coded black, white, red, green, yellow, brown, blue, orange, gray, purple, tan, and pink in clockwise rotation. The outer core is wrapped with mylar tape which is surrounded with an inner jacket of type I synthetic resin with a minimum wall thickness of 0.093 inches and an outside diameter of 1.120 $\pm$ 0.015 inches.

The strength member of the cable is a spiral wrap of 24 armor wires, each 0.134 inches in diameter, that surrounds the inner jacket. The outside diameter of the armor bundle is 1.400 inches and each galvanized steel armor wire has a tensile strength between 50,000 and 70,000 pounds per square inch. Around the armor wire is an outer jacket of type I synthetic resin with an overall outside diameter of 1.836 inches.

When splicing the cable there must be complete electrical continuity through each of the sixteen conductors with no reduction in conductor cross section. Connections must be made between wires of common color in both the inner and outer cores. Similarly, the braid must be electrically connected across the splice without loss of current carrying capacity and the spacing between the inner and outer cores and the braid connection must be generally maintained.

The dielectric material covering each conductor splice must be of adequate thickness to maintain equal or greater insulation resistance than that



TYPE 216 HARBOR DEFENSE CABLE

FIGURE 15

in the unspliced cable. The dielectric material must be completely watertight between the insulation on mating cables, must be free of any air cavities, and must form a complete bond with the conductor insulation on either side of the splice. Continuation of filaments or fillers through the splice is not required.

The inner jacket splice material must form a continuous watertight seal, free of internal air bubbles, between the inner jackets of the connecting cables and its outside diameter should be only slightly larger than that of the cable inner jacket.

When joining the armor wires by one of the methods previously described, the inner jacket and materials contained therein should be slackened to avoid any tensile loading within the inner core. Watertight integrity is not required outside the inner jacket and therefore no seal over the restored armor is necessary.

TOOLS AND MATERIALS REQUIRED

Tools

- o Knife
- o Small (1 1/2") paint brush
- o Shoemakers' No. 6 thread-unwaxed
- o Jacket cutting tool
- o Scissors
- o Diagonal wire cutters
- o Wire strippers (No. 14 wire)
- o Long nose pliers
- o Pencilling tool
- o Emery board
- o Strip of emery cloth
- o Pipe cleaner
- o Stiff (1/2") brush
- o Solder gun
- o Hot air gun

Materials

- o Shrink sleeve, 2"-5/8", 12" long
- o Trichloroethylene solvent
- o Paper towels
- o Masking tape
- o Plastic electrical tape, 3/4" width
- o Shrink sleeve tubing, 8 mm I.D., 24" long
- o Crimp connector sleeves for No. 14 wire
- o Solder paste
- o Coreless solder wire
- o Polyethylene irradiated tape, GE No. 210
- o Rubber electrical tape
- o Tinned copper tape, 1", 3M No. 24
- o Mastic tape

STEP-BY-STEP SPLICING PROCEDURE

Prior to starting the electrical splice it will be presumed that on one of the mating cables the outer jacket has been cut back and the armor wires

1 2 3 4 5 6

TYPE 216 SPLICING

FIGURE 16A

cut off or folded back so that there is sufficient length for sliding a 12-inch shrink sleeve over the inner jacket leaving the 10 inches required for the splice. On the mating cable the outer jacket and armor will have been cleared back leaving a length of at least 10 inches of the inner jacket for the splicing operation. The steps below are illustrated in Figure 16.

1. Set the two cable ends up in vises on separated work benches. Clean the inner jacket shrink sleeve with solvent and slide it on the long cable end to the point where it is out of the way. Nick the two inner jackets 10 inches back from the cable ends.

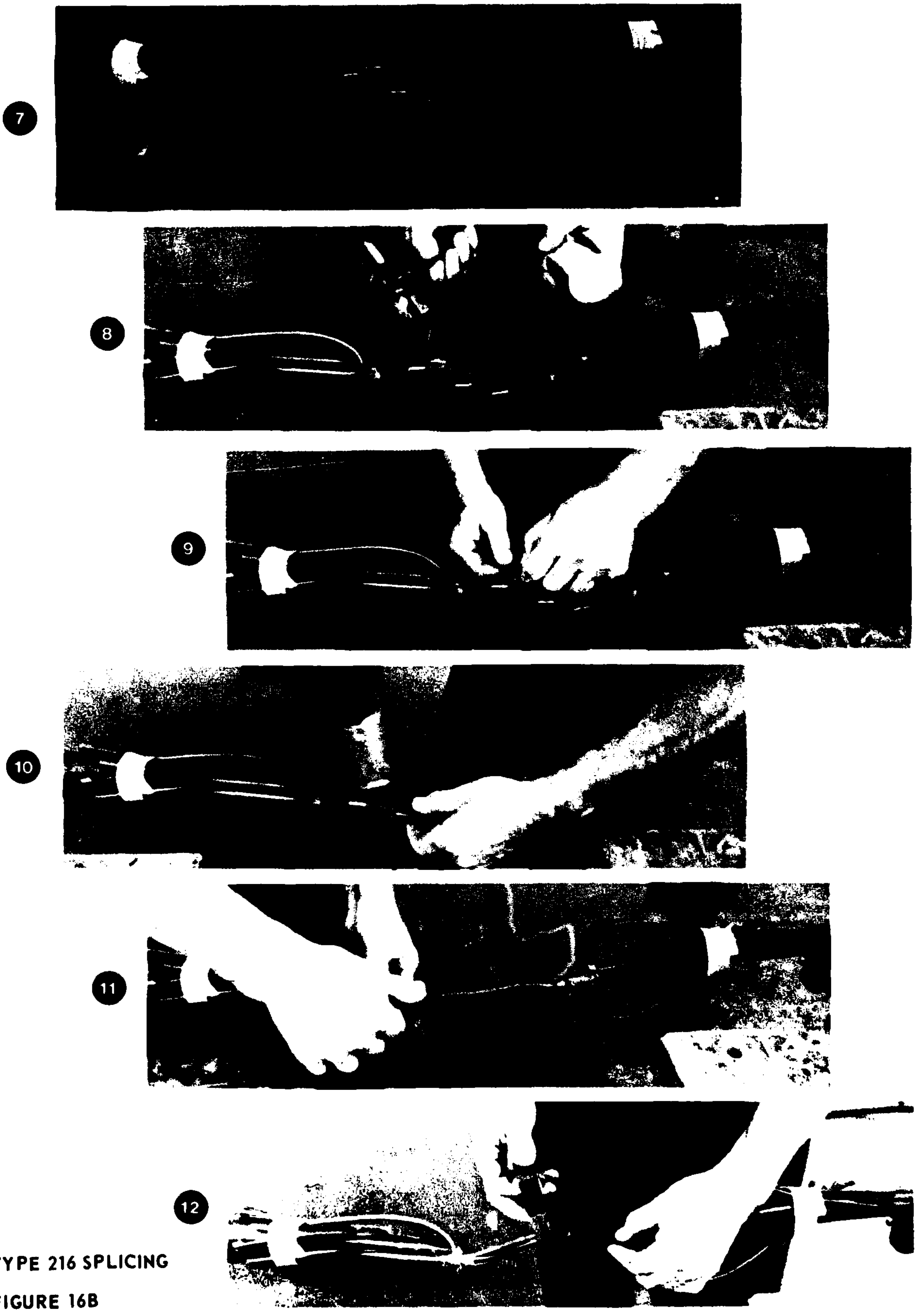
2. On one cable end, use the Shoemakers' thread to cut the inner jacket down to the mylar tape. Cut jacket with jacket cutting tool and remove from end of cable. Then remove mylar tape from around outer core of conductors.

3. Using paint brush, solvent, and paper towels, clean all mastic from each of the twelve outer conductors and from the next layer of mylar tape. Fold the outer core conductors back over the inner jacket and apply masking tape to hold them in place. Remove the mylar tape over the braid and clean with solvent.

4. Follow the same procedure on the other cable end - cut and strip off jacket, remove mylar tape, clean outer core conductors, fold back, and tape. Remove tape from braid and clean. Then move cables to position where braided cable ends overlap for full 10 inches.

5. Wrap electrical tape around jacket end of each cable extending in about 1 1/2" from cut-off jacket. Push braid back from end and cut back to end of electrical tape. Clean insulation on four inner core conductors with solvent, paint brush, and paper towels.

6. Cut inner core conductors with diagonals, staggering butted ends. Use wire strippers to strip half the crimp sleeve length of insulation off the end of the each of the four pairs of inner core conductors. Round the conductor ends with long nosed pliers. Use the pencilling tool to taper the insulation on each conductor end and roughen insulation with emery board or strip of emery cloth.



TYPE 216 SPLICING

FIGURE 16B

(7) Cut sixteen 1 1/2" lengths of 10 mm shrink sleeve tubing. Clean four lengths with pipe cleaner and solvent inside and out. Slide four on longer ends of inner core conductors. Clean conductor ends with solvent and stiff brush. Insert in crimp sleeves with sleeve slots up. Connect to conductors with crimping tool with dimples on top and then round off sleeves with crimping tool.

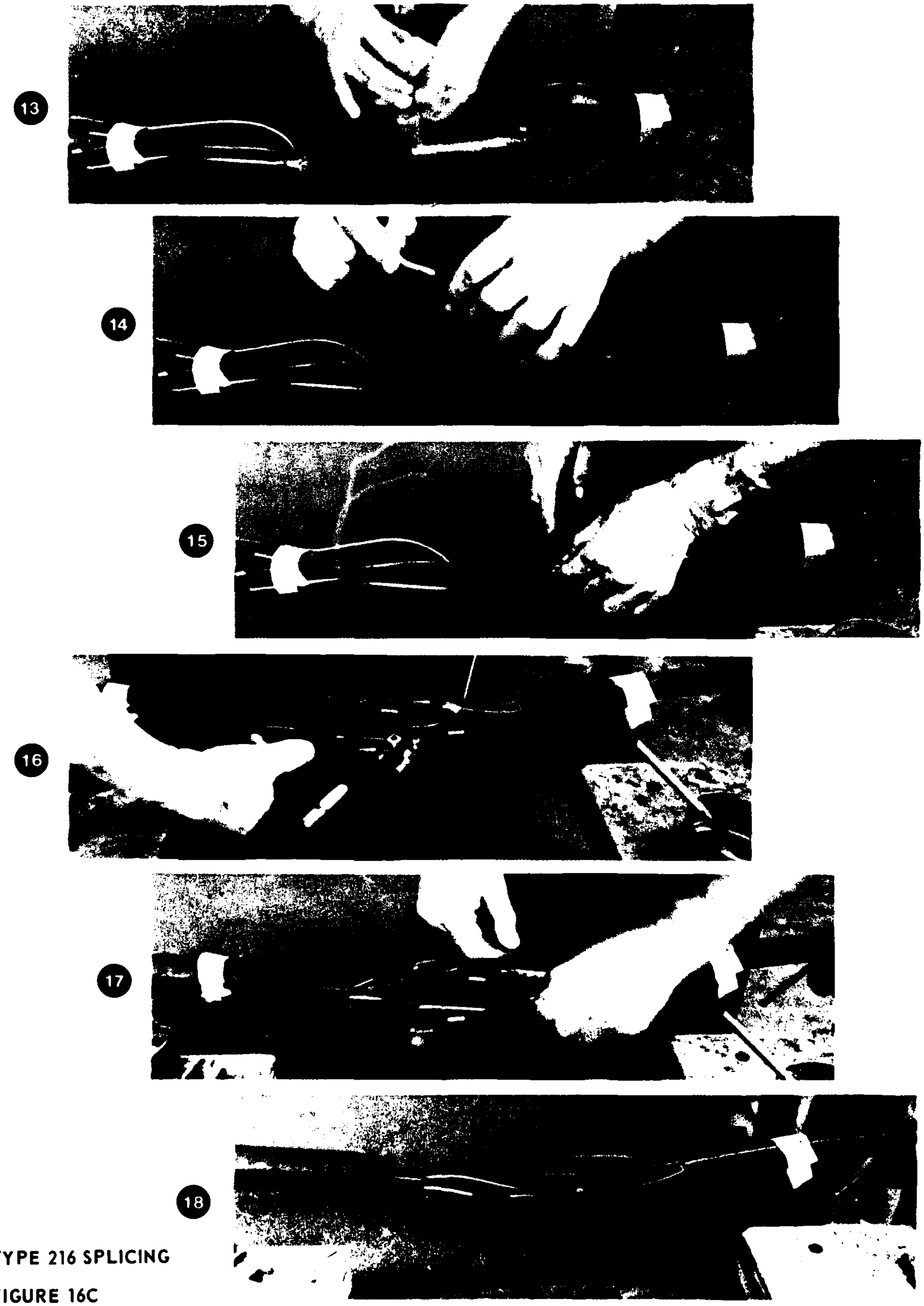
(8) Apply a dab of solder paste to the slot in each of the four crimp sleeves. Tin the soldering iron and heat one crimp sleeve, feeding the solder in through the slot until the solder fills the joint. Then clean each inner core splice thoroughly with solvent.

(9) Wash hands. Cut four lengths of irradiated polyethylene tape and wash with solvent. Wrap each crimped joint with two half-lapped layers of tape, starting in center and working to 1/2" beyond each crimp sleeve end. Heat end of tape to seal and cut off excess tape.

(10) Use hot air gun to heat each splice on all sides until tape turns from milky white to clear. Keep other wires and shrink sleeves clear of conductor where tape is being heated.

(11) Slide shrink sleeves over spliced joints in four inner core conductors. Heat shrink sleeves with hot air gun until insulation bulges slightly on either side. Then remove electrical tape from around braid at each end of spliced area.

(12) Pushing back the braid on one end, cover the four inner core conductors with a half-lapped layer of rubber electrical tape, starting and ending underneath the copper braid at each end. Pull the copper braid back over the rubber tape and apply a light layer of solder paste.



TYPE 216 SPLICING

FIGURE 16C

(13) Using the tinned copper tape, start wrapping over the braid at one end. Use enough tension to pull this tape to one-half its unstretched width. Wrap one half-lapped layer to the other end and over the copper braid. Then run a second half-lapped layer back to the starting point. Solder the tinned copper tape to the braid at each end.

(14) Clean with solvent. Apply another half-lapped layer of rubber tape across entire splice. Clean remaining conductor shrink sleeves with solvent and pipe cleaner. Cut first matching pair of outer core conductors with diagonals and slide shrink sleeve on one end. Strip ends, pencil down the insulation, roughen insulation with emery board or cloth and clean with stiff brush and solvent.

(15) Round ends of conductor with long nosed pliers and slide ends into a crimp connector sleeve. With sleeve slot up, crimp with dimple on top on each conductor and then use crimping tool to round the crimp sleeve. Repeat this process for the remaining eleven outer core conductors staggering joints to spread across length of splice.

(16) Apply a dab of solder paste to the slot on each crimp sleeve. Tin soldering iron, heat crimp sleeve, and feed solder wire in through slot until sleeve is full of solder. Use the same technique to solder the crimp sleeves on the remaining conductors of the outer core. Clean with solvent.

(17) Wash hands. Then cut twelve lengths of irradiated polyethylene tape and clean with solvent and paper towel. Apply two half-lapped layers of tape to each splice extending 1/2" over insulation from the crimp sleeve, seal with heat and cut off. Using wet cloth to isolate other conductors, heat each taped joint with hot air gun until tape turns from milky white to clear. Clean all joints with solvent.

(18) Slide shrink sleeves over each joint and heat each individually with hot air gun until insulation bulges at either end of sleeve. Clean again with solvent.

(19) Wrap spliced area with half-lapped layers of mastic tape extending one inch over inner jacket ends. Use enough layers to build up to thickness of inner jacket.

(20) Slide jacket shrink sleeve in place and start heating in center with hot air gun. Work from center out toward each end until sleeve has tightened completely down on splice. This completes the splicing of the Type 216 cable to the outside of the inner jacket. Armor restoration will be completed by one of the methods previously described.

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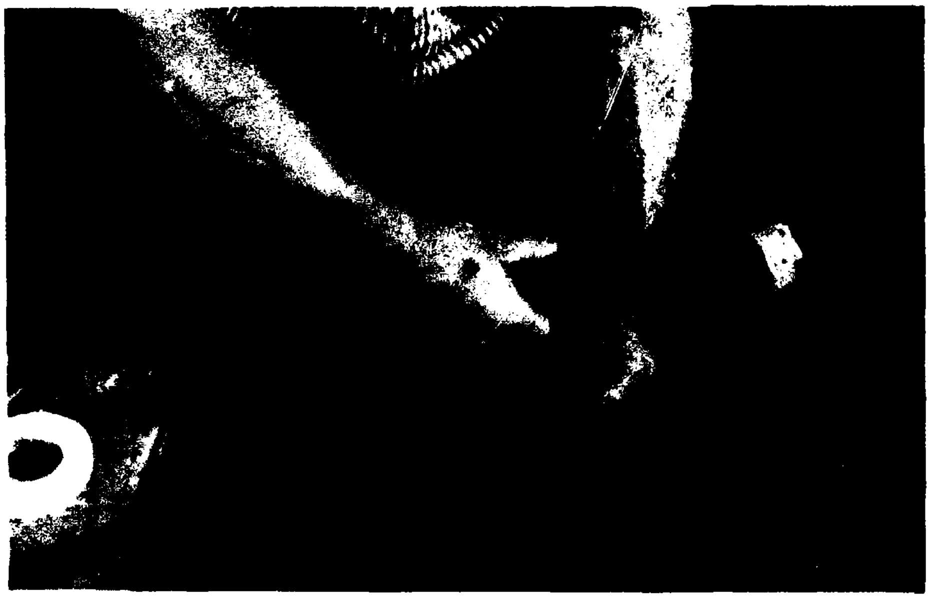

TYPE 216 SPLICING - FIGURE 16D

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ELECTRICAL TESTING PROCEDURES

There are two basic sets of conditions under which electrical measurements may be made. Under one set of conditions, both ends of the cable being spliced will be readily accessible to the splice house. Under the other set of conditions, only one end of the cable being spliced will be available at the splice house. The first set of conditions would occur, for instance, when the spliced cable was being run into a bin or cable tank aboard a cable-laying vessel. The second set of conditions would occur in a situation where the cable end was ashore, the vessel was laying cable out to sea, and new reels of cable were being spliced on as the vessel progressed seaward.

In addition to running tests on the spliced cable as each spliced length is added, it is intended to check the electrical integrity of each new reel of cable immediately prior to connecting it to a spliced cable that is being stowed in a tank or being installed by a cable-layer. The conditions under which these pre-splice tests will be made are identical to those in the first set of premises cited above, i.e., both ends of the cable on the reel are available to the splice house.

TESTS TO BE CONDUCTED AND THEIR PURPOSE

The required tests include a resistance test on all conductors, an insulation resistance test on conductor insulation and jackets, and a capacitance test on conductor insulation and jackets.

The conductor resistance test is performed to ensure that there is electrical continuity over the total length of each conductor including the spliced sections. This will tell whether there are any breaks in a conductor and whether the electrical splicing has been performed in a satisfactory manner. The resistance of a number of conductors that have been spliced together should be no greater than the sum of the resistances of the individual conductors or, in other words, the conductance should not be reduced by the splices.

The insulation resistance test is made to determine whether there are any flaws in the insulation between conductors and between conductors and the cable armor. It would be desirable to see whether the insulation resistance between conductors and between conductors and the armor in the spliced areas was as good as or better than that in the unspliced lengths of cable.

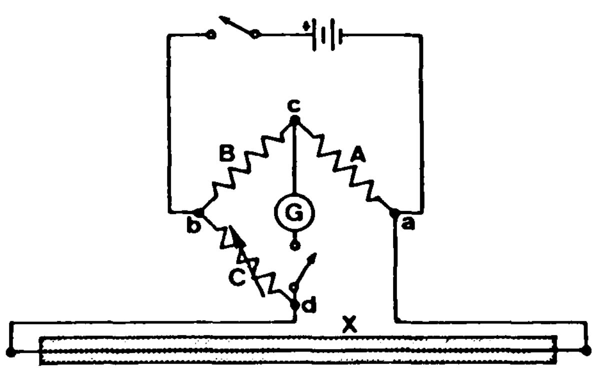
However, from a practical standpoint it is difficult to detect any flaws of much lesser magnitude than a dead short through the insulation by this technique for any significant lengths of cable. This is the case because the insulation resistances of connected lengths of cable are essentially in parallel and the total insulation resistance drops each time a new length of cable is spliced in place.

The insulation capacitance test is made to determine the dielectric characteristics of the spliced cable. Two conducting electrodes, separated by a dielectric, constitute a capacitor. If a positive charge is placed on one electrode of a capacitor, an equal negative charge is induced on the other. The dielectric properties of the medium between the electrodes relate to its ability to conduct *dielectric lines*. This is in distinction to its *insulating* properties which relate to its ability to conduct electric current. For example, air is an excellent insulator but ruptures dielectrically at low voltage. Air is not a good dielectric so far as breakdown strength is concerned.

Thus, the capacitance test affords an opportunity to detect any small air gaps or holes in the insulation that might lead to later failures due to collapse and rupture under pressure or direct water leakage. Fortunately, the capacitances of connected lengths of cable are directly additive and therefore a meaningful measurement can be obtained of any flaws along the length of a series of cables spliced together.

ELECTRICAL TEST MEASURING EQUIPMENT

For the conductor continuity and resistance tests a Wheatsone Bridge is used in conjunction with a 12 volt storage battery as illustrated by the diagram of Figure 17. Resistors from a fraction of an ohm to 100,000 ohms



WHEATSTONE BRIDGE FOR
CONDUCTOR RESISTANCE MEASUREMENTS

FIGURE 17

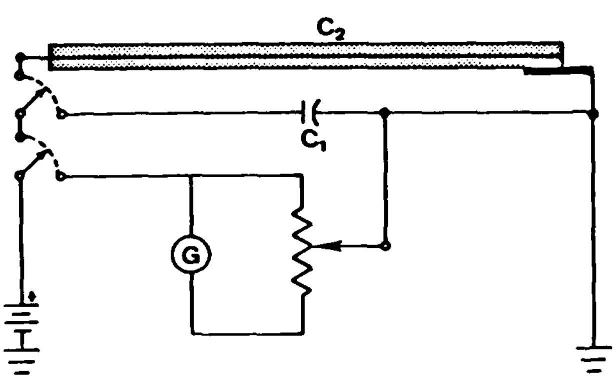
and more may be measured with a high degree of precision with this circuit arrangement. The bridge comprises four resistors, *ABCX*, connected as shown. *X* is the unknown resistance of the conductor being measured. *A* and *B* are ratio arms which are in even decimal ohms as 1, 10, 100, etc. The battery, or other low voltage DC source, is connected across *ab*. A galvanometer, *G*, of moderate sensitivity is connected across *cd*. The values of *A* and *B* are so chosen that three or four significant figures in the value of *C* are obtained. *A* and *B* can be made equal. The bridge is balanced by adjusting the rheostat *C* until the reading on the galvanometer is zero and:

$$X/C = A/B$$

or, when $A = B$ then $X = C$ and the resistance of the conductor will be equal to the resistance setting on the rheostat.

For the insulation resistance tests a Megger is used. This is an instrument that indicates insulation resistance directly on a scale. It consists of a small hand-driven generator which generates approximately 500 volts. A clutch slips when the voltage exceeds the rated value. The current through the unknown insulation resistance flows through a moving element consisting of two coils fastened rigidly together, but which move in different portions of the magnetic field. A pointer attached to the spindle of the moving element indicates the insulation resistance directly. These instruments have a range up to 2000 megohms.

The dielectric strength of the insulation can be measured by a capacitance test using the direct-discharge method. This consists of a comparison of the discharge from a standard condenser of known capacity with the discharge from the cable. The connections are shown in Figure 18. The standard



MEASUREMENT APPARATUS FOR CAPACITANCE TEST

FIGURE 18

condenser of capacity C_1 is charged for 10 seconds and then discharged through the galvanometer; the galvanometer deflection D_1 is noted. The cable of capacity C_2, with the distant end open, is then charged by the same battery and the galvanometer discharge deflection D_2 is noted. The cable capacitance is given by $C_2 = C_1D_2/D_1$.

TEST CONNECTIONS AND TESTING - BOTH CABLE ENDS AVAILABLE

If a cable tank or bin storage is being used aboard a cable-laying vessel, the first bottom coil in the tank should be run back to the splice house with the end brought inside to the measuring equipment rack. The ends of the conductors and the armor should then be stripped and arranged for easy connection to the instruments. The other end of this cable will be available for connection to the armor and conductors when the end is stripped back for making the splice. At this point, the cable end will be secured to the work bench in reasonable juxtaposition to the measuring equipment.

An additional cable should be run from the reel support rack into the splice house and measuring equipment rack. The conductors and armor on both ends of this cable should be stripped for easy connection both to the measurement equipment and to the accessible cable end at the center of each reel. The other end of this cable from the cable reel will be available for connection to the armor and conductors when it is stripped back for making the splice. It too will be secured to a work bench and handy to the measuring equipment.

The set-up for the continuity test will require connecting the two ends of each conductor across the points *ad* of the Wheatstone Bridge, Figure 17. For each conductor wire, for the shielding braid if incorporated, and for the armor wires, the resistance is measured by closing the switch in the battery circuit and then momentarily closing the switch to the galvanometer to check the direction and amount of deflection. The rheostat will then be adjusted and the momentary use of the galvanometer repeated until the imbalance is within its range. The rheostat can then be fine tuned until the galvanometer shows no current flow and the resistance can be read on the rheostat setting.

The set-up for the insulation resistance test will involve connecting the Megger to only one end of each cable with the conductors on the opposite end of each cable being open and separated from each other. The insulation

resistance shall be measured on the cable in the tank or bin each time a length is spliced in and on each new reel of cable prior to splicing. The resistance between conductors and between conductors and shielding braid or armor shall be measured as follows for the different types of cables.

- Type 201: Between conductor and braid and between braid and armor.
- Type 203: Between black and white, white and red, red and black conductors. Between each conductor and the armor, with the other two conductors being grounded to the armor.
- Type 204: Pair black and white conductors and pair red and green conductors with connections at the ends of the cable about to be spliced with the other ends open. Test between black/white pair and red/green pair and between each pair and the armor with the other pair grounded to the armor.
- Type 210: Form two groups of conductors with connections between the conductors of a group being made at the ends of the cable about to be spliced with the other ends open. The first group shall consist of the conductors that are color coded white, red, yellow, blue, and gray; the second group shall be conductors color coded black, green, brown, orange, and purple. (For the older cables, all of the black conductors in the outer ring will be part of one group.) Test between the first group and the second group, between the first group and the armor with the second group grounded to the armor, and between the second group and the armor with the first group grounded to the armor.
- Type 216: Form two groups of conductors with connections between the conductors of a group being made at the ends of the cable about to be spliced with the other ends open. The first group shall consist of the red and black inner core conductors and the outer core conductors color coded black, red, yellow, blue, gray, and tan. The second group shall consist of the white and green inner core conductors and the outer core conductors color coded white, green, brown, orange, purple, and pink. (For the older cables, all of the black conductors in the outer core will be part of one group.) Test between the first group and the second group with the second group connected to the armor and to the braided shield. Repeat the test with the first group connected to the armor and to the braided shield.

The specified insulation resistance is at least 10,000 megohms per 1000 feet at 60° F. With only 3000 to 5000 feet of cable on a cable reel, the insulation resistance of the cable on a single reel may well exceed the 2000 megohm capacity of the Megger. If this occurs, the insulation test on the single cable reel prior to splicing may be deleted and these resistance tests can be limited to the longer lengths of spliced cable stowed in the tank or bin.

The set-up for the capacitance test will involve connecting the capacitance measuring circuit to one end of each cable only with the opposite ends being open and separated from each other. The capacitance shall be measured on the cable in the tank or bin each time a length is spliced in and it shall be measured on each new reel of cable prior to splicing. It would be advisable to conduct the former test immediately after making the splice and before the cable is fed into the tank or bin. This applies to the continuity tests and insulation resistance tests as well so that any splice failure can be repaired before the splice leaves the splice house.

For this capacitance test, the conductors are to be grouped in the same manner as for the insulation resistance tests. However, the capacitance tests will not be required between conductors but only between the single conductors or groups of conductors and the armor (which is considered to be grounded). Thus, the capacitance measurements are required as follows for the different types of cables.

- Type 201: Between conductor and armor and between braid and armor.
- Type 203: Between each conductor and the armor with the other two conductors being grounded.
- Type 204: Test between each of the two pairs of conductors and the armor with the other pair grounded.
- Type 210: Test between the first group of conductors and the armor with the second group grounded to the armor; test between the second group and the armor with the first group grounded.
- Type 216: Test between the first group of conductors and the armor with the second group connected to the armor and to the braided shield; test between the second group of conductors and the armor with the first group connected to the armor and to the braided shield.

For all capacitance tests the negative side of the battery is grounded

to the armor of all cables being tested. The standard condenser is charged and discharged and then the cable "condenser" is charged and discharged and the capacitance is calculated from the two galvanometer readings. The rheostat is adjusted as necessary to utilize the maximum amount of galvanometer scale possible.

TEST CONNECTIONS AND TESTING - ONE CABLE END AVAILABLE

If cable is to be set out from a cable-layer in a manner such that the distant end is not available for test connections, the test arrangements will be somewhat different although the same general principles will be in effect. In such a cable-laying program it can be assumed that the cable reels to be spliced in will be aboard the cable-layer and that both ends will therefore be available to the splice house. Thus, the testing of each reel prior to splicing in will be identical to the procedure described in the foregoing section.

On the cable with the unavailable distant end, different connections will be required for the continuity, or conductor resistance tests. The set-up for the continuity test will require connecting pairs of conductors together at the distant end so that the measurements will actually be made of the "loop resistance" of pairs of conductors from the splice house out to the end of the cable and back again.

In order to prepare the cable for these tests the distant end will have to be specially connected and sealed. The conductors that make up each pair will be spliced together and effectively treated to prevent exposure to sea water using the splicing techniques previously outlined. The pairs to be connected at the distant end for each type of cable are delineated below.

- Type 201: Connect the conductor and the braided shield and insulate with watertight covering.
- Type 203: Connect all three conductors and insulate.
- Type 204: Connect the black and white conductors together, the red and green conductors together, and insulate.
- Type 210: Connect the following pairs of conductors together and insulate from other pairs and from the sea: white and black; red and yellow; green and brown; blue and gray; orange and purple.
- Type 216: Connect the following pairs of conductors together and insulate from other pairs and from the sea: braided shield and armor;

red and black inner core conductors; white and green inner core conductors; outer core conductors black and red, white and green, yellow and blue, brown and orange, gray and tan, purple and pink.

The continuity or resistance test will require connecting the splice house end of each of these pairs of conductors across the points *ad* of the Wheatstone Bridge, Figure 17, and measuring the loop resistance of each pair of conductors. This will be done from the cable-layer end of each reel of spliced in cable before and after the cable is overboarded into the water.

The set-up for measuring the insulation resistance of this overboarded cable will involve connecting the Megger to the splice house end of each spliced-in reel of cable before and after the added reel is overboarded into the water. The resistance between conductors and between conductors and shielding braid and armor shall be measured as follows for the different types of cables.

- o Type 201: Between the single conductor and the armor.
- o Type 203: Between any of the three conductors and the armor.
- o Type 204: Between the black conductor and the red conductor, between the black conductor and the armor, and between the red conductor and the armor.
- o Type 210: Form two groups of conductors by making the following connections. First group: white to red to blue. Second group: green to orange. Test between first group and second group, between first group and armor with second group grounded to armor, and between second group and armor with first group grounded to armor.
- o Type 216: Form two groups of conductors by making the following connections. First group: inner core black to outer core black to yellow to gray. Second group: inner core white to outer core white to brown to purple. Test between first group and second group, between first group and armor with second group grounded to armor, and between second group and armor with first group grounded to armor.

The set-up for capacitance test on the overboarded cable will involve connecting the capacitance measuring circuit to the splice house end of the overboarded cable with the negative side of the battery connected to the cable armor. This test will be required at the cable-layer end of each reel of

spliced-in cable before and after the cable is overboarded into the water.

For the capacitance test, the conductors are to be grouped in the same manner as for the insulation resistance tests. However, the capacitance tests will not be required between conductors but only between the single conductors or groups of conductors and the armor (which is considered to be grounded). Thus, the capacitance measurements are required as follows for the different types of cables.

- o Type 201: Between conductor and armor.
- o Type 203: Between any one conductor and the armor.
- o Type 204: Test between black conductor and the armor with the red conductor grounded; test between the red conductor and the armor with the black conductor grounded.
- o Type 210: Test between the first group of conductors and the armor with the second group grounded; test between the second group of conductors and the armor with the first group grounded.
- o Type 216: Test between the first group of conductors and the armor with the second group grounded; test between the second group of conductors and the armor with the first group grounded.

The negative side of the battery is grounded to the armor and the additional ground shown in Figure 18 also grounded to the armor. The standard condenser is charged and discharged and then the cable "condenser" is charged and discharged with the capacitance being calculated from the two galvanometer readings. The rheostat is adjusted as necessary to use the maximum amount of galvanometer scale possible.

RECORDING OF ELECTRICAL TEST DATA

Careful records shall be kept of all test data on forms that have been developed prior to each cable-laying operation. These should include a designation of each reel of cable that is used together with data on the cable such as supplier, year manufactured, length, condition of conductors, insulation, jackets, and armor, diameters of components, number of armor wires, color coding of conductors, conformance with specifications, and sketches to show just where each reel was spliced into the cable system.

The measurements of conductor resistance, insulation resistance, and capacitance should be recorded for both the spliced length of cable and for

each added reel of cable. Calculations should be made as to what the measured values should be each time a measured reel of cable is spliced in and these should be compared with the measured values for the total length to assess the adequacy of each splice before and after the cable is flaked into a tank or bin or is overboarded.

The measurement of each reel of cable prior to splicing will be the basis for including it in the system or rejecting it because of suspected defects. Similarly, the comparison of calculated values and measured values for each splice will form the basis for taking corrective action before a splice is considered satisfactory.

These records shall be kept in such form that they can become a part of the "as-built" drawings and will serve as an aid in locating and repairing any flaws in the system that may occur at a later date.

This step-by-step procedure of data measurement and recording is an extremely important function and should not be undertaken in a casual manner. Careful pre-operation planning should include making up jumpers, connection cables, and any jigs or fixtures that will speed up the measurement process and advance measurements of cable reels when delivered to the job site may save valuable time at sea or during the fitting out period. Computer programs for hand calculators based upon prior knowledge of cable characteristics may be helpful in assessing the quality of each splice as it is completed and the measurements are taken.

It is highly recommended that the cable splicing, testing, and record keeping requirements be carefully delineated in the project execution plan for each cable-laying project.

APPENDIX A

MILITARY SPECIFICATION
CABLES, POWER, ELECTRICAL
SUBMARINE, NAVY STANDARD HARBOR DEFENSE

MIL-C-15479C(SHIPS)
17 March 1958
SUPERSEDING
MIL-C-15479B(SHIPS
1 September 1954

MILITARY SPECIFICATION

CABLES, POWER, ELECTRICAL,

SUBMARINE, NAVY STANDARD HARBOR DEFENSE

1. SCOPE

1.1 Scope.- This specification covers standard submarine cables for use in harbor defense systems. These cables are intended for use as loop, signal, control and hydrophone links between components of water stations and between water stations and shoring stations.

1.2 Classification.- Standard submarine cables shall be of the following types, as specified (see 6.1):

Type 201 - Single conductor armored coaxial signal cable.
Type 203 - Three conductor armored magnetic loop tail cable.
Type 204 - Four conductor armored lateral or main hydrophone cable.
Type 210 - Ten conductor armored herald control and magnetic loop control cable.
Type 216 - Sixteen conductor armored main hydrophone cable.

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standards and drawings, of the issue in effect on date of invitation for bids, form a part of this specification.

SPECIFICATIONS

FEDERAL
L-P-590 - Plastic Compound, Molding and Extrusion, Polyethylene.
QQ-W-461 - Wire, Steel (Carbon); Bare and Zinc Coated.

MILITARY
MIL-C-17 - Cables, Radio Frequency; Coaxial, Dual Coaxial, Twin Conductor, and Twin-Lead.
MIL-C-915 - Cable, Cord and Wire, Electrical (Shipboard Use).

NAVY DEPARTMENT
General Specifications for Inspection of Material.

STANDARDS

MILITARY
MIL-STD-104 - Limits for Electrical Insulation Color.

DRAWINGS

BUREAU OF SHIPS
RE-10D724 - Reel, Steel Cable.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Other publications - The following document forms a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply:

A.S.T.M. STANDARDS
Designation B8-41 - Untinned Copper Wire.

(Application for copies should be addressed to the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa. 19103)

3. REQUIREMENTS

3.1 Material.- The material shall be as specified in the applicable paragraphs of Specification MIL-C-17, the American Society for Testing Materials Standards, and as specified herein.

3.2 Conductor wire.- All individual conductors shall meet the requirements of the American Society for Testing Materials Designation B8-41 for untinned copper wire. When repairs or joints are made in the conductor, the work shall be so performed that the joint and adjacent conductor is as strong and durable electrically and mechanically as the original wire. The wire size of individual strands shall be within plus or minus 0.002 inch.

3.2.1 Conductor strand sealing.- All individual conductors shall be strand sealed. The sealing compound shall not have any deleterious effects on the electrical, physical, or chemical properties of the conductors (see 3.4.1)

3.3 Conductor insulation.- All individual conductors shall be insulated with dielectric material conforming to Specification L-P-590. Unless colored material is required herein, the dielectric shall conform to type II, grade 4 of Specification L-P-590. When colored material is required herein, the dielectric shall conform to type II, grade 5 of Specification L-P-590. The insulating compound shall fit closely to the conductor with a pronounced adhesion which shall not prevent stripping the insulation when splicing.

3.3.1 All individual insulated conductors of the specified types, when tested under the conditions specified in section 4, shall withstand the voltage shown in table I. Either alternating current (a.c.) or direct current (d.c.) voltage may be used for all voltage tests at the option of the person making the test. The voltage source shall deliver the specified voltage under load.

Table I - Test-voltages.

Type	Volts a.c. root mean square (r.m.s.)	Volts d.c.
201	15,600	46,800
203	9,200	27,600
204	5,000	15,000
210	5,000	15,000
216	5,000	15,000

3.3.2 The conductor resistance, when tested in accordance with section 4, shall conform to the limits per 1000 feet shown in table II.

Table II - Conductor resistance.

Type	Maximum d.c. conductor resistance ohms per 1000 feet at 25° Centigrade (C).
201	0.66
203	1.00
204	2.52
210	2.52
216	2.52

3.3.3 Insulation resistance.- The insulation resistance of the individual insulated conductors and of the completed cable shall be at least 10,000 megohms per 1000 feet at 60° Fahrenheit (F), when tested as specified in 4.5.7.

3.4 Fillers.- Where specified, fillers or filaments shall be cabled with the insulated conductors to form a firm, well-rounded cross-section. The filaments shall consist of a material such as that used for conductor insulation, and shall be completely noncontaminating to the materials used for conductor insulation (see 3.3), tapes (see 3.6), and inner jacket (see 3.7) with respect to undesirable electrical, mechanical, or chemical effects.

3.4.1 Fillers for watertight construction.- In addition to the fillers specified in 3.4, all cables shall contain sealing compounds to provide watertight construction within the limits specified in the appendix to Specification MIL-C-915, except that the maximum acceptable limits shall be 1 cubic inch for types 204, 210, and 216 and 3 cubic inches for types 201 and 203. The sealing compounds shall not have any deleterious effects on the electrical, physical, or chemical properties of the conductors, conductor insulation, tapes, or inner jacket.

3.5 Color coding.- All insulated conductors shall be color coded in accordance with Standard MIL-STD-104 and with the further stipulations of this specification.

3.6 Tapes.- Where specified, a tape shall be applied helically to the cable with an overlap of approximately 20 percent of the width of the tape which shall prevent deletrious effect due to possible migration of the plasticizer from the synthetic resin jacket and shall have sufficient mechanical strength to maintain a firm well-rounded core.

3.6.1 Marker tape.- A continuous heat and moisture resistant marker tape, approximately 1/8 to 1/4 inch wide, shall be inserted between the tape and inner synthetic resin jacket of each cable and shall repeat the following information at approximately 1-foot intervals: Navy type number of cable, manufacturer's name and plant location, contract number, serial number, and year of manufacture.

3.7 Inner jacket.- A jacket of type I synthetic resin, conforming to Specification MIL-C-17, or equivalent, shall be applied over the taped core.

3.8 Armor wire.- Armor wire shall be galvanized steel wire with a tensile strength between 50,000 and 70,000 pounds per square inch (p.s.i.) and an elongation of not less than 10 percent in 10 inches after application to the cable. The zinc coating shall be in accordance with type 3 of Specification QQ-W-481.

3.8.1 The permissible variations over or under the specified nominal diameter of the armor wire shall be 0.004 inch.

3.8.2 The armor wire shall be capable of withstanding not less than 35 twists in a length equivalent to 100 diameters. The twist shall be in a plane perpendicular to the longitudinal wire axis and the twist shall be at a rate of 90 degrees per second.

3.8.3 Armor wire shall be applied to the cable helically with an even tension and a left hand lay at an angle of approximately 20 degrees and the number of wires shall be such as to insure approximately 95 percent coverage at the pitch circumference of the armor where the pitch diameter is equal to the outer diameter of the inner cable jacket plus the diameter of the armor wire. The wire shall be so preformed that it will remain in proper position and permit maximum flexibility of the finished cable. All armor wire joints shall be welded and thoroughly cleaned after welding and coated with zinc. Joints so treated shall be capable of meeting all requirements specified for the original wire.

3.9 Outer jackets.- A jacket of type I synthetic resin, conforming to Specification MIL-C-17, shall be applied over the armor. It shall not be tubed, but shall fit the form of the armor as closely as possible and shall have a smooth outer surface.

3.10 Mechanical requirements.- All cables shall meet the applicable requirements of Specification MIL-C-17, when tested under conditions specified in section 4.

3.10.1 All cables shall be capable of bending without injury about a mandrel 30 inches in diameter to permit processing by cable handling equipment aboard the cable laying vessel.

3.11 Minimum manufactured lengths.- All insulated conductors and jacketed cores shall be manufactured in continuous integral multiples of cable lengths specified (see 5.1.1).

3.12 Splicing.- If the contract or order provides for cable to be spliced at the place of manufacture before shipment, either before or after armoring, the order in which the lengths are to be spliced together and the arrangement of the conductors in the splice shall be determined from a splicing diagram which shall be furnished to the contractor by the bureau or agency concerned or by the Government inspector. All splices shall be made in accordance with this splicing diagram.

3.12.1 Methods of splicing.- On all cable splices made by the manufacturer, the conductors shall be butt brazed or soldered. The splices shall be so made that all parts affected in the process shall be as strong and durable, electrically and mechanically, as the remainder of the cable.

3.12.2 Armor splicing.- On cable spliced after armoring, the armor splice may be made by laying back the wire in its original position and electrically butt welding as specified in 3.12.1 to form a complete splice, or the armor wires may be laid back in position one at a time parallel with the splice. As an armor wire from one side is brought into position, one from the opposite side shall be laid in place beside it, so that they will interlock in the center of the splice. Care shall be taken to remove the sharp bend at the temporary serving. The wire shall be evenly distributed around the splice and squeezed into position, if necessary, with cable splicing clamps to form a smooth round splice, as small in diameter as possible. Place a serving of 10 turns of 0.134 diameter galvanized iron serving wire around the center of the splice, drawing it as tightly as possible with the serving stick. On each side of this serve, select four armor wires (six if the armor is light) spaced equidistantly around the splice, bend them back over the center serving, and hammer and squeeze them down snugly with the other armor wires to form an interlocking joint. Serve the balance of the splice with 0.134 inch diameter galvanized iron serving wire, drawn as tightly as possible with the serving stick. If the armor is smaller than 0.134 inch diameter, the serving wire shall be of the same diameter as the armor. To start the serving, loop the serving wire around one of the armor wires and lay the end parallel with the armor so that it will project beyond the farther end of the serving. When the serve is completed, the two ends of the serving wire shall be twisted together for 1 inch and hammered down parallel with the serve. Start each serving as close as possible to the center serving, and serve towards the ends of the splice. The final turn shall be made and secured about 1 inch before the end of the jacket is reached, taking care that the armor wires do not injure the jacket while serving.

3.12.3 The serving stick or device used shall be so constructed that it does not materially injure the galvanized coating of the serving or armor wire during the serving operation.

3.12.4 A consecutive number will be assigned for each splice on the splicing diagram. Each splice shall be marked in duplicate with this number by means of bands of iron wire placed on the cable at points 3 feet from each end of each splice, except where it interferes with the extrusion of the outer jacket. The number of turns of iron wire so placed shall coincide with the number of the splice. In order to facilitate counting, the turns shall be applied in groups of five turns with a 1-inch spacing between groups, example: Splice No. 12 would consist of two bands of five turns each and one band of two turns.

3.12.5 After completing the splice of the inner jacket, the splice shall be tested in accordance with 4.5.6.

3.13 Type 201 - single conductor armored coaxial signal cable.-

3.13.1 The inner conductor shall be approximately No. 8 AWG, 7 strand, untinned copper wire, meeting the requirements of 3.2. Each strand shall be 0.049 inch in diameter.

3.13.2 The inner conductor shall be insulated as specified in 3.3, and the average diameter of the insulated conductor shall be not less than 0.460 inch and the minimum wall thickness shall be not less than 0.141 inch.

3.13.3 A shielding braid of approximately No. 28 AWG (0.0126 inch diameter) untinned copper wire shall be applied over the insulated conductor with a minimum braid angle of 35 degrees and a minimum coverage of 88 percent.

3.13.4 A tape shall be applied over the copper shield in accordance with 3.6.

3.13.5 A synthetic resin jacket, as specified in 3.7, shall be applied over the taped core, the average outer diameter of which shall be 0.749 $\pm$ 0.015 inch and the minimum wall thickness shall be 0.093 inch.

3.13.6 An armor of galvanized steel wire, as specified in 3.8, 0.134 inch in diameter, shall be applied over the inner jacket.

3.13.7 A synthetic resin jacket, as specified in 3.9, with a total wall thickness at any point about the circumference of the cable of not less than 0.1875 (12/64) inch shall be applied over the armor. The wall thickness shall be measured from the outer surface of the armor wire to the outer surface of the outer jacket along a cable radius passing through the diameter of an armor wire. The maximum outer diameter of the finished cable shall not exceed 1.465 inches.

3.14 Type 203 - Three conductor armored magnetic loop tail cable.-

3.14.1 The three conductors shall be approximately No. 10 AWG, 7 strand, untinned copper wire, meeting the requirements of 3.2. Each strand shall be 0.040 inch in diameter.

3.14.2 Each conductor shall be insulated as specified in 3.3, the average diameter of each insulated conductor shall be not less than 0.304 inch and the minimum wall thickness of insulation shall be not less than 0.083 inch.

3.14.3 A minimum of three filaments in accordance with 3.4 and the three insulated conductors shall be laid up spirally with a right hand lay to form a firm, well-rounded core.

3.14.4 The insulated conductors shall be color coded in accordance with 3.5 as folllows:

Core - Black, white, red

3.14.5 A tape shall be applied over the core in accordance with 3.6.

3.14.6 A synthetic resin jacket, as specified in 3.7, shall be applied over the taped core, the average outer-diameter of which shall be 0.885 ± 0.015 inch and the minimum wall thickness shall be 0.093 inch.

3.14.7 An armor of galvanized steel wire, as specified in 3.8, 0.134 inch in diameter shall be applied over the inner jacket.

3.14.8 A synthetic resin jacket, as specified in 3.9, with a total wall thickness at any point about the circumference of the cable of not less than 0.1875 (12/64) inch shall be applied over the armor. The wall thickness shall be measured from the outer surface of the armor wire to the outer surface of the outer jacket along a cable radius passing through the diameter of an armor wire. The maximum outer diameter of the finished cable shall not exceed 1.602 inches.

3.15 Type 204 - four conductor armored lateral or main hydrophone cable.-

3.15.1 The four conductors shall be approximately No. 14 AWG, 7 strand, untinned copper wire meeting the requirements of 3.2. Each strand shall be 0.0253 inch in diameter.

3.15.2 Each conductor shall be insulated as specified in 3.3, the average diameter of each insulated conductor shall be not less than 0.176 inch and the minimum wall thickness shall be not less than 0.043 inch.

3.15.3 The four insulated conductors, with filaments in accordance with 3.4, if necessary, shall be laid up spirally with a right hand lay to form a firm, well-rounded core.

3.15.4 The insulated conductors shall be color coded in accordance with 3.5 as follows:

Core - Black, white, red, green.

3.15.5 A tape shall be applied over the core in accordance with 3.6

3.15.6 A synthetic resin jacket, as specified in 3.7, shall be applied over the taped core, the average outer diameter of which shall be 0.655 ± 0.015 inch and the minimum wall thickness shall be 0.093 inch.

3.15.7 An armor of galvanized steel wire, as specified in 3.8, 0.109 inch in diamter shall be applied over the inner jacket.

3.15.8 A synthetic resin jacket, as specified in 3.9, with a total wall thickness at any point about the circumference of the cable of not less than 0.1875 (12/64) inch shall be applied over the armor. The wall thickness shall be measured from the outer surface of the armor wire to the outer surface of the outer jacket along a cable radius passing through the diameter of the armor wire. The maximum outer diameter of the finished cable shall not exceed 1.321 inches.

3.16 Type 210 - ten conductor armored herald control and magnetic loop control cable.-

3.16.1 The 10 conductors shall be approximately No. 14 AWG, 7 strand, untinned copper wire, meeting the requirements of 3.2. Each strand shall be 0.0253 inch in diameter.

3.16.2 Each conductor shall be insulated as specified in 3.15.2.

3.16.3 A minimum of two filaments in accordance with 3.4 and two insulated conductors shall be laid up spirally with a right hand lay to form a firm, well-rounded inner core. Eight additional insulated conductors, with filaments in accordance with 3.4, if necessary, shall be laid up spirally with a left hand lay to form a firm, well-rounded outer core.

3.16.4 The insulated conductors shall be color coded in accordance with 3.5 as follows:

Core - White, black.
Outer layer - Red, green, yellow, brown, blue, orange, gray, and purple (clockwise rotation)

3.16.5 A tape shall be applied over the outer core in accordance with 3.6.

3.16.6 A synthetic resin jacket, as specified in 3.7 shall be applied over the taped core, the average outer diameter of which shall be 0.935 ± 0.015 inch and the minimum wall thickness shall be 0.093 inch.

3.16.7 An armor of galvanized steel wire, as specified in 3.8, 0.134 inch in diameter shall be applied over the inner jacket.

3.16.8 A synthetic resin jacket, as specified in 3.9, with a total wall thickness at any point about the circumference of the cable of not less than 0.1875 (12/64) inch shall be applied over the armor. The wall thickness shall be measured from the outer surface of the armor wire to the outer surface of the outer jacket along a cable radius passing through the diameter of the armor wire. The maximum outer diameter of the finished cable shall not exceed 1.651 inches.

3.17 <u>Type 216 - sixteen conductor armored main hydrophone cable</u>.-

3.17.1 Each of the 16 conductors shall be approximately No. 14 AWG, 7 strand, untinned copper wire. Each strand shall be 0.0253 inch in diameter.

3.17.2 Each of the 16 conductors shall be insulated with dielectric, as specified in 3.3, to an average diameter of not less than 0.183 inch and minimum wall thickness of 0.049 inch.

3.17.3 Four insulated conductors, with filaments in accordance with 3.4, if necessary, shall be laid up spirally in a right hand lay to form a firm, well-rounded inner core.

3.17.4 The insulated conductors shall be color coded in accordance with 3.5 as follows:

Inner conductors - Black, white, red, green
Outer conductors - Black, white, red, green, yellow, brown, blue, orange, gray, purple, tan, and pink (clockwise rotation).

3.17.5 A tape shall be applied over the core formed by the four inner insulated conductors. A shielding braid of No. 28 AWG (0.0126 inch diameter) untinned copper wire shall be applied over the taped core with a minimum braid angle of 35 degrees and a minimum coverage of 88 percent.

3.17.6 A tape shall be applied over the shielding braid in accordance with 3.6.

3.17.7 Twelve additional insulated conductors, with filaments in accordance with 3.4, if necessary, shall be laid up spirally with a left hand lay over the taped inner core to form a firm, well-rounded outer core.

3.17.8 A tape shall be applied over the outer core in accordance with 3.6.

3.17.9 A synthetic resin jacket, as specified in 3.7, shall be applied over the taped core, the average outer diameter of which shall be 1.120 ± 0.015 inches and the minumum wall thickness shall be 0.093 inch.

3.17.10 An armor of galvanized steel wire, as specified in 3.8, 0.134 inch in diameter shall be applied over the inner jacket.

3.17.11 A synthetic resin jacket, as specified in 3.9, with a total wall thickness at any point about the circumference of the cable of not less than 0.1875 (12/64) inch shall be applied over the armor. The wall thickness shall be measured from the outer surface of the armor wire

to the outer surface of the outer jacket along a cable radius passing through a diameter of an armor wire. The maximum outside diameter of the finished cable shall not exceed 1.836 inches.

3.18 Workmanship- Workmanship shall be as specified in Specification MIL-C-17, the American Society for Testing Materials Standards and as specified herein.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of tests.- The methods of sampling, inspection, and tests conducted on the cable fall within the following classifications:

(a) Acceptance inspection.
(b) Production inspection:
    (1) On individual conductors.
    (2) On completed cable.

4.2 Sampling.- For purposes of sampling for acceptance inspection the Government inspector shall select from the first 1000 feet of completed cable the number of feet, not in excess of 100 feet, (usually a 50 foot sample is sufficient) deemed necessary by the Government laboratory for the tests.

4.3 Acceptance inspection.- Acceptance inspection shall be made at a Government laboratory designated by the bureau or agency concerned on samples selected as specified in 4.2. Acceptance inspection shall consist of any tests considered necessary by the Government laboratory to determine compliance with the requirements of this specification and shall include the following tests:

Test	Reference
Armor wire	4.5.1, 4.5.1.1, and 4.5.1.2
Cable dimensions	4.5.2
Voltage	4.5.3
Conductor resistance	4.5.4
Outer jacket integrity	4.5.5
Inner jacket	4.5.6
Insulation resistance	4.5.7
Watertight construction	4.5.8
Heat aging	MIL-C-17
Cold bending	MIL-C-17
Continuity	MIL-C-17
Dielectric strength	MIL-C-17
Capacitance	MIL-C-17
Attenuation (60 c.p.s. to 100 kc.)	MIL-C-17
Impedance	MIL-C-17

4.4 Production inspection.- Production inspection specified hereinafter shall be made at the place of manufacture by or under the supervision of the Government inspector.

4.4.1 Conductor insulation.- Each completed length of insulated conductor, before the application of any covering, shall be completely immersed in fresh water at room temperature for a period of 16 hours; after which period of time and while still immersed, it shall be subjected to the following tests:

Test	Reference
Voltage	4.5.3
Conductor resistance	4.5.4
Insulation resistance	4.5.7

4.4.1.1 In addition to the tests specified in 4.4.1, the Government inspector may require any additional tests he may consider necessary to determine conformance with this specification.

4.4.1.2 Each individual length of insulated conductor that meets the specified requirements shall be accepted and each length that fails shall be rejected.

4.4.2 Completed cable.- Each length of completed armored and jacketed cable except as specified in 4.4.2.4, shall be completely immersed in fresh water for a period of not less than 1 hour to insure complete wetting and shall then be subjected to the test specified in 4.5.5. Each length of completed armored and jacketed cable shall also be subjected to the following tests:

Test	Reference
Armor wire	4.5.1
Cable dimensions	4.5.2
Voltage	4.5.3
Conductor resistance	4.5.4
Outer jacket integrity	4.5.5
Insulation resistance	4.5.7
Watertight construction	4.5.8

4.4.2.1 In addition to the tests specified in 4.4.2, the Government inspector may require any additional tests he may consider necessary to determine conformance with this specification.

4.4.2.2 Each individual length of completed cable that meets the specified requirements of this specification shall be accepted and each length that fails shall be rejected, but may be repaired in accordance with 4.4.2.3 and retested.

4.4.2.3 Repairs.- Lengths of completed cable that fail to meet the tests specified in 4.4.2 due to a localized fault or faults may be repaired and reoffered for inspection.

4.4.2.3.1 Where repairs are made to the cable, the work shall be performed in such a manner that all parts affected in the process shall be as strong and durable electrically and mechanically as the remainder of the cable. The armor may either be spliced in accordance with 3.12 or may be laid back in its original position and electrically butt welded. If the armor is welded, the joints in the several armor strands shall be staggered over a distance of not less than 30 feet, and the welds thoroughly coated with zinc.

4.4.2.3.2 The number of repairs or splices shall not exceed one for each length of completed cable not exceeding 5000 feet in length, with one additional repair or splice permitted for each additional 5000 feet or fraction thereof, provided that no two armor splices shall be less than 1000 feet apart.

4.4.2.4 If the contract or order calls for delivery of the cable either spliced or armored in carload lengths and coiled in a car, each carload length shall be tested after loading as specified in 4.4.2 through 4.4.2.3, inclusive except that it may be tested either wet or dry.

4.5 Tests.-

4.5.1 Armor wire.- The wire shall be tested in accordance with Specification QQ-W-461 to determine conformance with 3.8, and shall be subjected to coverage test to determine conformance with 3.8.3. The wire shall withstand four 1-minute dips in the Preece test.

4.5.1.1 Measurement of diameter.- Measurements shall be made to determine conformance with 3.8.1.

4.5.1.2 The wire shall be subjected to a twist test to determine conformance with 3.8.2.

4.5.2 Cable dimensions.- All dimensions of the completed cable shall be measured to determine compliance with this specification.

4.5.2.1 The average diameter of the conductor insulation and outer diameter of the inner jacket shall be taken as the mean of the maximum and minimum diameter measured at any one point.

4.5.2.2 Measurements may be made with any type of micrometer reading to 0.001 inch, suitable for measurement of conductors of this character. All measurements shall be made before the conductors are taped or cabled. If the measurements of any coil or reel do not conform to the limits specified, that coil or reel shall be rejected.

4.5.3 Voltage test.- Unless otherwise specified in the contract or order, potentials as required by table I, shall be applied between the conductor or conductors under test for a period of 5 minutes. In the tests listed herein "ground" shall be considered the armor wires of the completed cable connected together to act as a single conductor. If a.c. potential is used, the frequency shall be not less than 25 nor more than 100 cycles per second.

Type	Test
201	(a) The specified voltage shall be applied between inner conductor and the braided shield.
	(b) Two thousand five hundred volts shall be applied between the shield and ground.
203, 204, and 210	(a) Alternate conductors shall be connected so as to form two groups of conductors and specified voltage shall be applied between the two groups and one group grounded.
	(b) The test shall be repeated with other group grounded.
216	(a) Red and black inner conductors and the black outer conductors shall be connected to form one group, and the green and white inner conductors and the colored outer conductors to form a second group. The specified voltage shall be applied between the two groups with one group grounded and connected to the braided shield.
	(b) The test shall be repeated with other group grounded and connected to the braided shield.

4.5.4 Conductor resistance.- The conductor resistance shall be measured to determine conformance with 3.3.2 and table II.

4.5.5 Outer jacket integrity.- The integrity of the outer jacket shall be tested by applying at least 2,500 volts a.c. (r.m.s.) or a d.c. voltage equivalent to 2,500 volts a.c. (r.m.s.) peak to peak between all the armor wires connected together and the outer jacket (the water) for a period of 5 minutes. The purpose of this test is to detect flaws and imperfections in the outer jacket.

4.5.6 Inner jacket.- The splice of the inner jacket shall be immersed in water and a voltage test applied between the insulated conductors in accordance with 4.5.3. Any splice not meeting this requirement shall be rejected.

4.5.7 Insulation resistance.- Each insulated conductor and the completed cable shall have an insulation resistance of at least 10,000 megohms per 1000 feet at 60°F., when tested with a direct current potential of not less than 200 volts applied for 1 minute.

4.5.8 Water leakage shall be measured across the area bounded by the external surface of the inner jacket of each cable type to determine conformance with 3.4.1.

4.6 Test records.-

4.6.1 Acceptance report.- A complete acceptance inspection record with conclusions as to acceptability of the cable shall be prepared by the Government laboratory making the acceptance

AD-A163 498 MANUAL FOR FIELD SPLICING OF HARBOR DEFENSE CABLES(U) 2/2
NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC
CHESAPEAKE DIV JAN 82 CHES/NAVFAC-FPO-1-82(4)

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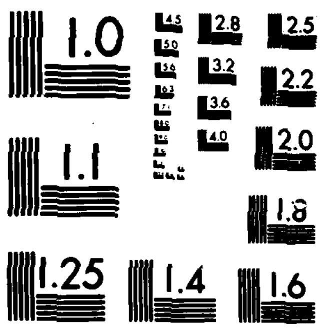

MICROCOPY RESOLUTION TEST CHART
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inspection and forwarded to the bureau or agency concerned for approval. A duplicate copy shall be furnished the contractor. No cable shall be considered accepted until the test record is approved by the bureau or agency concerned.

4.6.2 Production report.- The reports of the required production inspection, in tabular form as set forth in the appendix, shall be prepared by the contractor. At least once each month, one copy of each report, for the cable manufactured during the period, shall be certified by the Government inspector and forwarded to the bureau or agency concerned. No cable shall be shipped or accepted until the required reports are approved by and certified by the Government inspector.

4.7 Inspection procedures.- For Naval purchases, the general inspection procedures shall be in accordance with General Specifications for Inspection of Material.

5. PREPARATION FOR DELIVERY

5.1 Shipment.- Preparation for shipment shall be as follows:

5.1.1 Lengths.- Unless otherwise specified in the contract or order, the completed cable of each type shall be delivered as specified in table III.

Table III - Minimum cable lengths harbor defense submarine cables.

Type	Minimum length	Maximum reel dimensions (inches)	
	Feet	Flange diameter	Inside traverse
201	5,000	84	48
203	5,000	84	48
204	3,000	84	48
210	5,000	84	48
216	3,000	84	48

5.1.2 Reels.- The actual length of the cable on each reel after final inspection at the place of manufacture shall be not less than specified in the contract or order.

5.1.2.1 Steel reels.- Cable shall be furnished on a nonreturnable steel reel conforming to the requirements of Drawing RE-10D724, Rev. C, except that drum ring, part No. 3, may have dimensions of 1/4 by 1-1/2 inches or 1/2 by 1-1/2 inches.

5.1.2.2 The reel shall be plainly marked to indicate the direction in which it should be rolled so as not to loosen the cable on the reel. The head of each reel shall be stenciled or lettered with waterproof ink or paint as follows:

Contractor's name and address.
Name and address of consignee.
Contract and item number.
Quantity and type number of cable.
Reel number.
Net weight of cable.
Net weight of reel.
Expiration date reel returnable for credit (month-year) (as applicable).

5.1.3 Carload shipment.- When the contract or order provides for shipment of cable in one length or various lengths in carload lots (gondola cars), the actual length or lengths of the cable after final inspection at the place of manufacture, shall be not less than specified in

the contract or order. The cable shall be coiled in flat even layers, starting at the outside and working toward the center of the coil, stopping at a point where the turns will not lie flat and excessive bending will become injurious to the cable, the diameter of the inner coil being dependent on the size and type of cable being coiled. The cable shall then cross-over to the outside again and successive layers be made in a similar manner. The cross-overs shall be distributed so that they do not all appear on one side of the coil. Pieces of dunnage slightly thicker than the diameter of the cable shall be placed alongside the cable on each cross-over so that excessive weight will not fall on this part of the cable. The ends of the cable shall be brought out clear of the coil for testing purposes. The cable shall be properly braced with shoring and antiabrasion protection to prevent shifting. The cable shall be properly roofed in order to minimize fire hazards and other injuries to the cable. One end of each length of cable shall have a tag securely attached showing the following information:

Contractor's name and address.
Name and address of the consignee.
Contract and item number.
Quantity and type number of cable.
Net weight of cable.

5.1.4 End seals.- All cable ends shall be sealed in accordance with Specification MIL-C-915.

6. NOTES

6.1 Ordering data.- Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type required (see 1.2).
(c) If carload lots are desired (see 4.4.2.4 and 5.1.3).
(d) If less than standard reel lengths are desired (see 5.1.1).

Notice.- When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacure, use, or sell any patented invention that may in any way be related thereto.

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